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GEOLOGICAL MAGAZINE

VOL. LXXXVI. No. 2. MARCH–APRIL, 1949

An Alkali Facies of Granite at Granite-Dolomite Contacts in Skye

By C. E. TILLEY

(PLATE I)

ABSTRACT

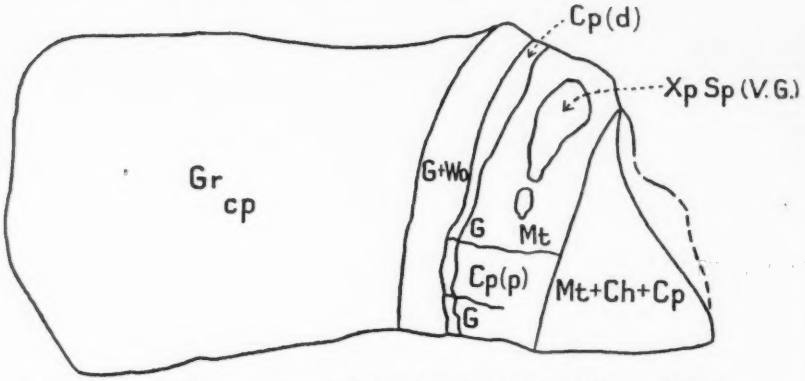
The development of an alkali pyroxene-bearing facies of granite at the contact of the Beinn an Dubhaich granite of Skye with Durness dolomites is associated with a skarn formation involving magmatic transfer of alumina. The significance of the processes at work in this and related examples is discussed.

THE investigation of the skarns associated with the contact of the Durness dolomites and the Tertiary Beinn an Dubhaich granite of Skye has afforded, in a region of detailed survey mapping, an opportunity for the study of endomorphic processes at granite–dolomite contacts, on which subject in Skye, data have hitherto been lacking. In a note on the mineralogy of these skarns (Tilley, 1948), reference was made to the occurrence of localized marginal facies of the granite, linked with the skarns. It is one of these examples I propose to discuss in the present contribution.

As detailed by Harker (1904) in the Skye memoir the Beinn an Dubhaich granite mass is a uniform medium-grained hornblende-biotite type with granitoid texture, resembling in its mineralogy some companion granites of the Red Hills. At the dolomite contact skarns the hornblende and biotite give place to clinopyroxene and the texture of the granite may be considerably affected, becoming not infrequently finer-grained. The petrographical character of these marginal facies of the granite is found to stand closely related to the nature of the exomorphic skarns with which they are intimately associated.

The particularly marginal facies of granite now under discussion is characteristically associated with a group of zoned skarns which have as inner members against the granite a grossularite-wollastonite assemblage. Such examples are particularly to be found at No. 1 Prospect, Kilchrist, at Kilbride, and best of all, at a locality on the southern border of the granite, 1 mile E.S.E. of Camas Malag. The characteristic feature of this alkali granite type of endomorph is the association of a deeply coloured clinopyroxene with quartz and a microperthitic felspar. This facies is normally limited to a few inches from the skarn contact, but at the last locality referred to above, the

zone reaches a foot or more in width. At this locality the alkali granite forms a lens in the marble close to the main granite contact: as exposed this is about 15 feet long, with a width of not less than 4 feet, but the whole contact with the marble is not seen. Specimens collected from the lens appear to be wholly of alkali type. The rock is a grey-white granite spotted with black pyroxene, often fine-grained but sometimes with larger microperthites showing typical micrographic texture



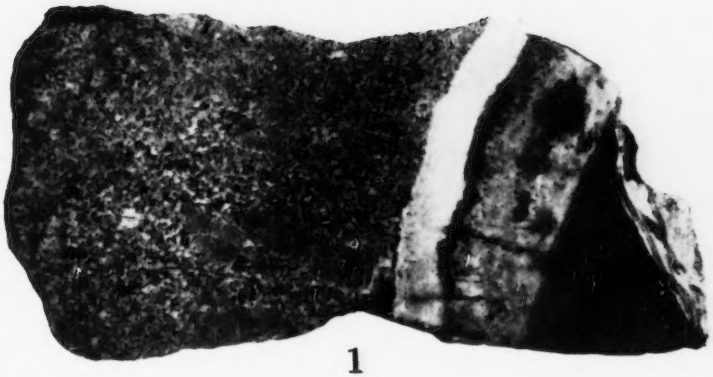
TEXT-FIG. 1.—Diagrammatic sketch and explanation of Fig. 1, Plate I.
Gr_{cp} (clinopyroxene granite), G grossularite, Wo wollastonite, Cp (p) pale clinopyroxene, Cp(d) dark clinopyroxene, Xp xanthophyllite, Sp spinel, V vesuvianite, Mt magnetite, Ch chondrodite.

EXPLANATION OF PLATE I

FIG. 1.—Marginal facies of granite associated with zoned skarn, No. 1 Prospect, Kilchrist (× ⅔).
The granite at the marble contact bears green soda clinopyroxene and shows larger microperthites with micrographic texture: immediately bordering it is a zone of grossularite-wollastonite. This is followed by a thin zone of dark clinopyroxene (Cp(d)), a coarse pale clinopyroxene zone (Cp(p)) with dark patches rich in spinel, vesuvianite, grossularite, and xanthophyllite, and finally the ore zone built of magnetite, clinopyroxene, and chondrodite. Analysis of the grossularite–wollastonite zone of this specimen is given in Table 5, No. 1.

FIG. 2.—Biotite-hornblende granite of the Beinn an Dubhaich mass, N. of Camas Malag, Loch Slapin (× ⅔).
Typical granitoid texture with white idiomorphic oligoclase. (For comparison with Fig. 1).

(cf. Plate I, fig. 1, from a Kilchrist example). Independent albite crystals are rare, usually this mineral appearing in streaky perthitic intergrowth, sometimes in broader plates continuous with orthoclase or as narrow fringes thereto. Accessory minerals include sporadic sphene.



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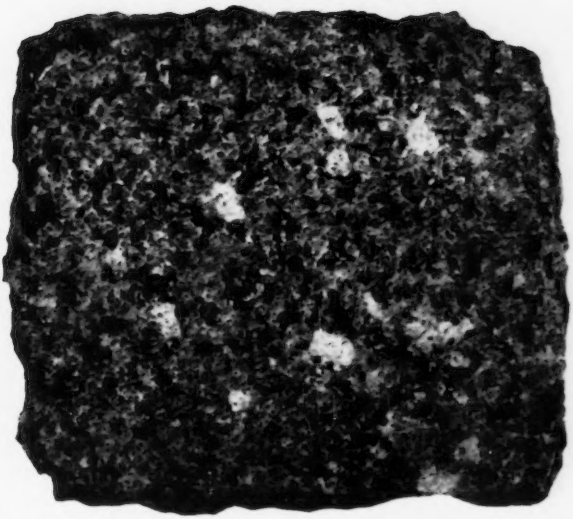


2

GRANITE-DOLOMITE CONTACTS IN SKYE.

The clinopyroxene varies considerably in colour in different examples; usually it is a pale green type, lighter at the core and often strongly zoned. At Kilchrist, where zoning is less pronounced, the pleochroism is α = light green, γ = yellow to brown green and $\gamma \wedge c = 53°$. These features correspond to a diopside-hedenbergite with small amounts of aegirine in solid solution. At the locality E.S.E. of Camas Malag the clinopyroxene of the lens is more strongly coloured and zoned with a central core showing $\gamma \wedge c = 60°$ and a narrow periphery, deeply coloured, almost straight extinction, optically negative, and having the properties of aegirine. The pleochroism of this aegirine is α and β = grass green, γ = brown green. Strong dispersion of the optic axes, $\rho > \nu$. These pyroxene crystals have completed their crystallization at a late stage, being moulded on the microperthite. The plagioclase associated with the orthoclase has a composition close to Ab_{97} (sections normal to the obtuse bisectrix give $\beta \wedge 010 = 15°$).

This rock and its separated clinopyroxene have both been analysed, the analyses being set down in Tables 1 (No. 3) and 2.

Besides clinopyroxene, some specimens of the lens, particularly those more remote from the contact (e.g. one 24 inches from the lower contact) contain scattered grains of arfvedsonite, sometimes enclosing the clinopyroxene. This arfvedsonite has the following pleochroism : α blue, bluish green, β blue, γ brownish, greenish brown. The sections do not extinguish in white light, and in sodium light yield values of extinction of $\alpha \wedge c = 35°$.

This description of the alkali granite can be compared with that of the normal granite from the same locality. The chief ferromagnesian mineral is brown biotite, with subordinate brown green hornblende. The felspars are microperthite and plagioclase, the latter subidiomorphic, medium grained rising to 3 mm. in diameter, and having the composition of oligoclase (An_{25}). Accessories include magnetite, apatite, and a little orthite.

Two analyses of closely similar granites from Kilchrist are set down in Table 1, Nos. 1 and 2 for comparison with that of the alkali granite already noted (Table 1, No. 3). The analyses of the normal granite, though somewhat more siliceous and poorer in iron oxides, show close resemblance to that recorded by Harker elsewhere in the Red Hills, at Druim Eadar da Choire.

The alkali character of the clinopyroxene granite is revealed in the high combined alkalis and low lime. Mineralogically, this is expressed in the abundant alkali felspars and in the nature of the clinopyroxene, which the separate analysis in Table 2 indicates as an aegirine hedenbergite. The norm of the rock shows the presence of acmite and wollastonite, pointing to a deficiency of alumina in relation to alkalis and to low values of FeO and MgO. The mode has been calculated

TABLE 1

	1	2	3	4	5	Norm	1a	2a	3a	4a	5a
SiO_2	73·99	74·88	75·33	71·23	71·20	Quartz	32·28	32·94	31·41	18·72	18·98
Al_2O_3	13·02	12·73	11·88	14·43	14·35	Orthoclase	27·80	29·47	42·47	35·58	37·92
Fe_2O_3	0·76	0·53	0·43	1·10	0·61	Albite	28·82	28·30	21·01	40·35	37·78
FeO	1·60	1·33	0·95	0·66	0·89	Anorthite	6·11	5·00	—	—	0·11
MnO	0·02	0·02	0·01	0·03	0·02	Acmite	—	—	0·46	0·92	—
MgO	0·31	0·25	0·08	0·26	0·25	Diopside	—	0·71	3·16	1·30	2·29
CaO	1·22	1·12	0·92	0·97	1·34	Hypersthene	2·65	1·82	—	—	—
Na_2O	3·43	3·33	2·55	4·90	4·47	Wollastonite	—	—	0·35	1·04	0·94
K_2O	4·74	4·99	7·18	6·04	6·41	Magnetite	0·93	0·70	0·46	0·93	0·93
H_2O+	0·22	0·79	0·23	0·11	0·02	Ilmenite	0·61	0·46	—	0·61	0·61
H_2O-	0·14	0·16	0·06		0·14	Apatite	—	—	—	—	0·35
TiO_2	0·32	0·18	0·06	0·36	0·35	Calcite	—	—	—	—	0·25
P_2O_5	0·05	0·05	0·08	0·07	0·16	Rest	0·43	1·02	0·44	0·27	0·18
CO_2	—	—	—	—	0·11	Mol. $\frac{Al_2O_3}{K_2O + Na_2O}$	1·21	1·17	0·99	0·99	1·00
	99·82	100·36	99·76	100·16	100·32	Mol. $\frac{K_2O}{Na_2O}$	0·91	0·97	1·86	0·81	0·95
Sp. Gr.	2·62	2·625	2·596		2·60						

1. Hornblende-biotite Granite, Trial pit near granite contact, No. 1 Prospect, Kilchrist (analyst J. H. Scoon).
2. Hornblende-biotite Granite, at edge of metasomatic vein in granite, No. 1 Prospect, Kilchrist (Analyst Geochemical Laboratories).
3. Aegirine-hedenbergite Granite, contact against grossularite-wollastonite skarn, 1 mile E.S.E. of Camas Malag (loc. K.) (Analyst Geochemical Laboratories).
4. Aegirine-augite Granite, Sviatoy Noss, Transbaikalia, P. Eskola (1920), p. 72.
5. Clinopyroxene granite, vein intrusion in marble, quarries at Port Shepstone, Natal (analyst J. H. Scoon).

from the analysis of the pyroxene and the composition of the plagioclase, and is presented in Table 3. The analysis itself can be compared with that of an aegirine-augite granite described by Eskola from

TABLE 2

	1	metals to 6 oxygens		
SiO_2	49·69	1·9747	2·00	
Al_2O_3	0·48	0·0224		
TiO_2	0·45	0·0133		
Fe_2O_3	8·79	0·2626		
FeO	18·23	0·6058	1·01	Acmite . 25·3
MnO	0·25	0·0084		Jadeite. . 1·9
MgO	1·98	0·1172		Diopside . 10·5
CaO	16·87	0·7180	1·01	Hedenbergite 62·5
Na_2O	3·79	0·2917		
K_2O	nil			
H_2O	nil			
	100·53			
Sp. Gr.	3·59			

1. Aegirine-hedenbergite in analysed Granite (Table I, No. 3) (Analyst H. C. G. Vincent).

TABLE 3

Aegirine-hedenbergite Granite, Skye

	Pyrox.	Or	Ab	An	Qz	Total
SiO_2	2·48	27·50	13·71	0·20	31·41	75·30
Al_2O_3	0·02	7·79	3·88	0·17		11·86
Fe_2O_3	0·43					0·43
FeO	0·91					0·91
MnO	0·01					0·01
MgO	0·09					0·09
CaO	0·84			0·09		0·93
Na_2O	0·19		2·36			2·55
K_2O		7·18				7·18
TiO_2	0·02					0·02
	4·99	42·47	19·95	0·46	31·41	99·28

Sviatoy Noss, Transbaikalia (Table 1, No. 4). Eskola has considered this rock as derived from his sviatonossites developed by reaction of granodiorite magma with limestone (or dolomitic limestone).

Petrographically, the Skye marginal granite shows great similarity too, to a rock described by Hatch and Rastall (1910) and du Toit

(1920) from Port Shepstone, Natal. Specimens of this Natal rock and its accompanying skarns are available at Cambridge and the rock described and figured by Hatch and Rastall (p. 511 and figure 2) has now been analysed for comparative purposes. The analysis is set down in Table 1, No. 5.

The rock is built of quartz, microperthite including patches and fringes of albite the composition of which is close to Ab_{97} (sections normal to (001) (010) having extinction angles of 13°). The clinopyroxene, unlike the Skye example, is not strongly zoned, but shows in places aegirine fringes. The main part of the crystals is pleochroic α grass green, γ yellowish to brownish green $c\wedge\gamma = 61°$. Sphene and apatite are accessories. In Table 4 is given a calculated mode with the calculated composition of the clinopyroxene based on the composition of the plagioclase and the allotment of Fe_2O_3 of the analysis to acmite. The calculation of the pyroxene composition can, of course, claim no great accuracy but is of interest in showing its sodic character which its optical properties attest. With that calculation may be placed the mode of the Sviatoy Noss rock, with its calculated pyroxene composition for further comparison (Table 4).

Before discussing the common features the three analyses of alkali granites possess, the environment of the Skye example calls for further description. It has already been noted that it is intimately associated with a grossularite-wollastonite skarn rather similar to that figured from Kilchrist. There the inner skarn zone is an intergrowth of grossularite and wollastonite 5–8 mm. thick, and having a composition 39 per cent grossularite, 61 per cent wollastonite, as seen from the analysis given in Table 5, No. 1. At the locality of the analysed alkali granite E.S.E. of Camas Malag, the nature of the skarn contact immediately adjacent to the granite is as follows: clinopyroxene granite | wollastonite $\frac{3}{4}$ mm. | grossularite with subordinate wollastonite 18 mm. | idocrase $\frac{1}{2}$ mm. | diopside 15 mm. | marble with forsterite little phlogopite and spinel. Here no ore skarn intervenes between the diopside zone and the marble.

The chief difference between this section and that at Kilchrist is the greater width of the inner zone of grossularite-wollastonite and its much higher content of grossularite. Analyses of the diopside zones from similar specimens at Kilbride show that this mineral there possesses a significant alumina content, the dark clinopyroxene zone showing 6·42 per cent Al_2O_3 and the pale zone 3·67 per cent. Comparison of the marginal granite with that of the two analyses of normal granite shows significant features, a drop in the CaO content as well as that of FeO, MgO, and Al_2O_3. The rock clearly gives no evidence of transfer of lime by diffusion from the dolomite, or sign that mutual reaction has taken place, despite the contrast in composition.

TABLE 4

	Aegirine-hedenbergite Granite, Marble Delta, Natal										Aegirine-augite Granite, Sviatoy Noss	
	Pyr.	Or	Ab	An	Qz	Ap	Sph.	Ct	Total	Pyr.	Pyroxene	Mode
SiO_2	2·60	24·55	24·59	0·50	18·69		0·26		71·19	50·68	50·63	
Al_2O_3		6·95	6·96	0·43					14·34		—	
Fe_2O_3	0·61								0·61	11·89	18·91	
FeO	0·88								0·88	17·15	12·46	Quartz . . 18·48
MnO	0·02								0·02	0·39	—	Microcline . 35·58
MgO	0·24								0·24	4·68	4·05	Plagioclase (Ab_{97}) . . 39·12
CaO	0·55			0·24		0·19	0·24	0·14	1·36	10·72	6·62	Clinopyroxene 5·83
Na_2O	0·23		4·23						4·46	4·49	7·33	Sphene . . 0·78
K_2O		6·41							6·41			
P_2O_5						0·16			0·16			
TiO_2							0·35		0·35			
CO_2								0·11	0·11			
	5·13	37·91	35·78	1·17	18·69	0·35	0·85	0·25	100·13	100·00	100·00	

On the other hand, the skarn has been enriched in alumina and silica, particularly as evidenced by the abundance of grossularite, and some alumina is also probably contained in the diopside zone beyond.

Assuming that transformation of dolomite into the skarn zones was accomplished without change of volume, it is of interest to calculate not only the material added to the skarns, but also that lost, in their development. These data are set out in Table 6 with respect to the analysed grossularite-wollastonite skarn, and for a skarn composed of pure grossularite. The chief additions, as already noted, are silica and

TABLE 5

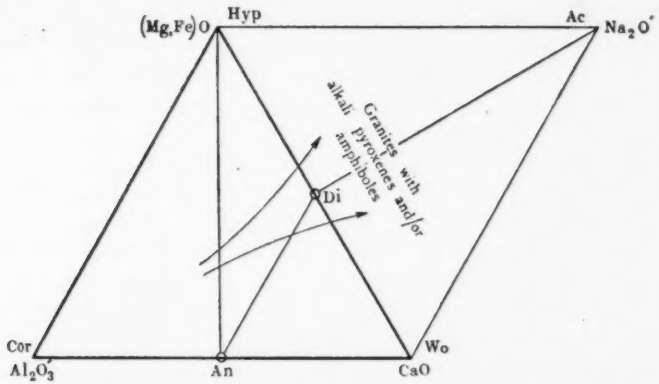
				Gain or loss in grms. per 100 c.c.	
	1	2	1a	2 → 1	2 → Gross
SiO_2	46·48			+ 147·34	+ 141·20
Al_2O_3	8·04			+ 25·48	+ 80·13
Fe_2O_3	0·92		Mode of 1	+ 2·91	
FeO	0·36		Grossularite . 38·47	+ 1·14	
MnO	0·19		Wollastonite . 60·32	+ 0·60	
MgO	0·39	21·74	Excess CaO . 0·84	− 61·16	− 62·39
CaO	43·24	30·43	Rest . . 0·62	+ 49·74	+ 44·34
Na_2O	nil		100·25		
K_2O	0·04				
H_2O −	0·02				
H_2O +	0·51				
TiO_2	0·05				
CO_2		47·82		− 137·24	− 137·24
	100·24				
Sp. Gr.	3·170	2·87			

1. Grossularite-wollastonite skarn, No. 1 Prospect, Kilchrist.
2. Dolomite (theoretical).

alumina, but they include also lime, while magnesia and CO_2 have been eliminated. There is no evidence that the eliminated magnesia has been transferred to the granite, and it is probable that it has migrated outward beyond the diopside zones. Conversely CaO, if equality of volume in metasomatism held, must have migrated inward from the limestone. These particular exchanges will be considered at greater length when the processes at work in the production of the multi-zoned skarns are discussed in a later communication.

The chemical and mineralogical data give clear evidence then of transfer of material from the magma—of silica and alumina particularly—and to this transfer must now be ascribed the petrographical change in the character of the marginal granite. The removal of

alumina in particular from the granitic liquid has led to a local impoverishment in this constituent which has had a resultant influence on the crystallization history of the marginal granite. In the calculated norm this deficiency in alumina under the molecular sum ($K_2O + Na_2O$), leads to the development of acmite and wollastonite also appears, owing to the relatively low values of FeO + MgO. (See Text-fig. 2.) The ferromagnesian minerals in the normal granite are both



TEXT-FIG. 2.—Plot to show effect of alumina removal from liquids of normal granitic composition (biotite, and biotite-hornblende granites) as expressed in the changing association of normative minerals. The arrow lines trace this change from the field of biotite, biotite-hornblende granites (close to the join An–Hyp) to that of the alkali granites (with alkali pyroxenes and/or alkali amphiboles. Normative compositions: Hyp (hypersthene); Di (diopside); Wo (wollastonite); Al_2O_3', normative corundum (Cor); Na_2O', femic soda (in acmite (Ac) and sodium silicate).

aluminous types (biotite and hornblende). With the changed composition these no longer appear and are replaced by a clinopyroxene, eventually bearing acmite. The modal pyroxene of the rock contains the acmite, diopside, and wollastonite of the norm, as well as the magnetite. But more than this for the plagioclase in equilibrium with the lime-pyroxene is not pure albite, but has an estimated composition of Ab_{97}. This is in harmony with the evidence of recent experimental work, which establishes that pure albite does not form from a liquid containing lime compounds (Bowen, 1945). In the case of the system albite-Ca pyroxene we may, perhaps, assume that the formation of plagioclase releasing soda follows a reaction of the type

$$2\,Na\,Al\,Si_3\,O_8 + Ca\,(Mg, Fe)\,Si_2\,O_6 \rightarrow Ca\,Al_2\,Si_2\,O_8 + (Mg, Fe)\,SiO_3 + Na_2\,Si_2\,O_5 + 3\,SiO_2$$

Accordingly, in the mode more than the calculated percentage of soda

allotted to acmite in the norm is contained in the clinopyroxene (see modal composition of Table 3). A similar alumina deficiency appears in the analysis of the Sviatoy Noss aegirine-augite granite and a similar lime content is reported in the modal plagioclase. Turning now to the alkali granite from the Marble Delta, Port Shepstone, though no acmite appears in the norm it is clear that the very small amount of anorthite shown in the norm represents less than the equilibrium amount in the modal plagioclase in association with the clinopyroxene, so that an excess of soda is available for absorption in the composition of the soda-bearing clinopyroxene which petrographic examination shows is present. The calculated modal composition of both Eskola's rock and the Port Shepstone granite are set down accordingly in Table 4. The alkali granite of Port Shepstone appears as a vein or sill intrusion in the dolomites of the Marble Delta, and is surrounded by skarn zones of which two types have been described. According to du Toit, the country rock granite is a biotite (or biotite hornblende) type, and specimens at Cambridge show that in addition to microcline, oligoclase or oligoclase-andesine is present. It is to be assumed that the alkali granite now under discussion has been derived from such a type through its contact with the dolomites. The specimen analysed formed part of the intrusion figured in Hatch and Rastall, a block 3 feet in longest dimension representing the cross-section of a vein in the marble surrounded by skarn zones successively from the granite contact: (1) phlogopite-olivine (dark mica zone) 2–5½ inches, (2) phlogopite-olivine (light mica zone) 2 inches, followed by ophicalcite and normal dolomite. This environment makes evident that K_2O, Al_2O_3 and SiO_2 have been transferred to the dolomite, but as the composition of phlogopite shows Al_2O_3 molecularly in excess of K_2O, the effect on the granite is toward a deficiency again of alumina. In the second type of skarn surrounding the "soda granite" of du Toit, the zones in succession are (1) scapolite-andesine, (2) andesine, (3) phlogopite, (4) marble with forsterite and chondrodite. These zones have been tabulated from a skarn succession in a specimen presented by Hatch and Rastall, and briefly referred to in their paper (p. 514). In this association the granite has lost by transfer to the skarns Al_2O_3, SiO_2, K_2O, and Na_2O, but again under conditions leading to a relative deficiency of alumina in the magma.

Both the Skye and Port Shepstone alkali granites are thus to be considered as a product essentially of a one-way transfer of material into carbonate sediments and their composition directly related to the mineralogical character of the skarn with which they are found in contact. The removal of alumina particularly has led to the precipitation of abundant potash felspar (microperthite) with which the magma was saturated and to the appearance of an effectively non-aluminous

member of the reaction series (pyroxene) in which excess soda resulting from the alumina deficiency is incorporated. There is no decrease in the total silica in the marginal granite of Skye ; the acidity has been maintained, and it is to be assumed that diffusion to the border facies was sufficiently active to maintain a relatively high silica content. The Skye granite shows the remarkable feature in addition of very high potash compared with the normal granite. There is no evidence to suggest that this has come about by selective transfer of soda into the skarns prior to crystallization of the rock. Whatever be the case, a soda-bearing potash felspar, now microperthitic in character, has separated abundantly from the liquid. If soda was not earlier removed some has moved finally in a residual liquid into the body of the neighbouring granite. A sodic residuum is suggested by the albitic fringes to the microperthite, as detailed in the description of the rock.

We may contrast the mode of development of the Skye alkali granite with that of the aegirine-augite granite from Sviatoy Noss, already noted. At that locality Eskola has described the production of sviatonossites by reaction of granodiorite with limestone. He has considered that assimilation has operated first by the production of andradite-clinopyroxene skarns at the granite contacts, and that fragments of this skarn have been absorbed at depth and subsequently crystallized out once more, resulting in the igneous assemblage of the sviatonossites. He has pointed out that the formation of grossularite-andradite has not only effected removal of silica and ferric oxide, but also alumina from the magma, and he traces the development of alkalinity, particularly to this alumina removal, inasmuch as its incorporation in garnet and in the associated clinopyroxene has left insufficient to form felspars with all the alkalis, particularly soda present, so that part of the soda goes with ferric oxide to form acmite in the clinopyroxene.

The derivation of an aegirine-augite granite in the Sviatoy Noss region is attributed to a further differentiation of the contaminated magma. Such an aegirine-augite granite, as we have seen, resembles closely the Skye example which we have derived more directly by transfer of alumina to the skarns without the intermediate step of assimilation. The development of sviatonossites in some force in Lake Baikal district points to the adequacy of the assimilation process under favourable conditions in producing these distinctive mildly alkali assemblages, but it is remarkable that similar rocks have not been more frequently recorded. Lacroix (1922), it is true, has described from the Ampasibitika district of Madagascar, andradite-rich syenites with aegirine-hedenbergite developed by reaction of Liassic limestones with siliceous granite, but in this case the original magma, carrying riebeckite and aegirine, was itself already alkaline. Detailed investigation

of granite-limestone (dolomite) contacts elsewhere may yet reveal if processes analogous to those now discussed, whether associated with assimilation or not, have been more widely operative, and thus permit a clearer conception of their significance in petrogenesis.

Appendix

Since the above account was written, a further analysis of a marginal facies of granite in Skye has been made.

The example comes from No. 1 Prospect, Kilchrist, and is from a companion specimen of that figured in Plate I, fig. 1. The granite contains sparse green clinopyroxene identical with that already described from Kilchrist (p. 83), abundant microperthite and quartz, accessory sphene, magnetite, and an occasional grain of orthite. Albitic plagioclase never occurs as individual crystals, but only as a fine constituent of the microperthite. The granite is clearly a potash-rich type like that already described. The analysis is set down below.

The analysis closely resembles that of the marginal facies of granite set down in Table 1 (No. 3). The hand specimen from which material came for analysis contained especially close to its margin with the grossularite-wollastonite skarn, small amounts of wollastonite and botryolite, in the form of later minute venules, as well as some secondary prehnite. Examination of the material actually analysed showed that this was not wholly free from this secondary lime-rich material. The figure of CaO (1·66) in the analysis is therefore high for the granite as consolidated, and this extraneous CaO accounts for part of the normative wollastonite. Apart from this feature, the marginal granite in its petrography and chemical analysis reflects the operation of processes discussed in the body of the paper.

		Norm		
SiO_2	74·69			
Al_2O_3	12·00	Quartz . . .	30·42	
Fe_2O_3	0·44	Orthoclase . . .	46·15	
FeO	0·71	Albite . . .	17·29	Ab_{97}
MnO	0·03	Anorthite . . .	0·56	
MgO	0·12	Diopside . . .	2·38	
CaO	1·66	Wollastonite. . .	1·85	
Na_2O	2·02	Magnetite . . .	0·70	
K_2O	7·78	*Sphene . . .	0·39	
H_2O+	0·17	* Estimated in place of ilmenite.		
H_2O-	0·20			
TiO_2	0·14	Mol. $\frac{Al_2O_3}{K_2O + Na_2O}$	1·02	
P_2O_5	tr.			
CO_2	nil	Mol. $\frac{K_2O}{Na_2O}$	2·51	
	99·96			

Clinopyroxene granite, marginal facies against skarn, No. 1 Prospect, Kilchrist. Analyst J. H. Scoon.

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A Starfish from the Glass Sand of Loch Aline

By RHONA M. MACLENNAN

(PLATE II)

ABSTRACT

An impression of the actinal surface of a starfish, possibly *Calliderma*, has been found at Loch Aline, N.W. Argyllshire, in Cretaceous white sandstone which hitherto has yielded no fossils. Indistinct traces of the ambulacral groves are present, otherwise only the outline is clearly defined. Carbonaceous matter associated suggests the fossil may have been desiccated in dry sand. The sandstone itself is a marginal deposit with millet seed frosted quartz grains of which the perfect rounding is masked by outgrowths of authigenic quartz.

THE Cretaceous white sandstone at Loch Aline, N.W. Argyll, which is now being worked as a glass sand by Messrs Tennant, Sons, and Co., Ltd., is one of the most interesting deposits of Mesozoic age, preserved by the Kainozoic lavas, on the West Coast of Scotland. It was first described as an estuarine deposit by J. W. Judd in 1878. This sandstone has since attracted much attention because of its remarkable purity—a silica content of 99·69 per cent is quoted in the Geological Survey Memoir for Mull, Loch Aline, and Oban (p. 116). The most important description of this rock is contained in the interesting paper by Sir Edward Bailey on " The Desert Shores of the Chalk Seas " (1924). He finds support for his theory that the Chalk seas owed their excessive clarity to the existence of a desert zone surrounding them, in the millet seed quartz grains which occur in abundance in the equivalent of the Loch Aline glass sand at Beinn Iadain, 7 miles to the north, and at Gribun, in Mull. Sir Edward Bailey concluded that the deposit probably represented material blown into the sea from a neighbouring desert.

No fossils have been recorded from this sand, apart from the indeterminate marine shells collected at Beinn Iadain by the Survey (Mull Pre-Tertiary Memoir, p. 116). Recently, however, the impression of a starfish was found by some of the quarry workers at Loch Aline, in a block of sandstone which was being conveyed to the crusher. Mr. A. D. Noel Paton, the manager, has given me permission to record this starfish (Plate II) which he has retained in his office at Loch Aline.

The exact location of the fossil is uncertain, since the block containing it was not found *in situ*. However, the sandstone, though normally friable, is in this case quite indurated, and it is probable that it came from a hard band about the middle of the rock.

The impression is of the underside of the starfish, and when first found had some black carbonaceous powder associated with it;

sufficient of this powder remains to discolour the specimen, and emphasize the few details that remain. In the absence of the calcareous plates, by means of which fossil starfish are identified, it is not possible to compare it closely with other described specimens. The body is fairly large, with stellato-pentagonal outline, and the margin sharply defined with a steep angle. The major radius—about 67 mm.—measures slightly more than one and a half times the minor radius. The inter-brachial arcs form a crescentic curve towards the arms, which taper abruptly. Little detail remains of the structures, apart from ridges and grooves seen fairly clearly in two arms (north-west and north in the plate) and indistinctly in a third (south-south-east). A central ridge, representing the ambulacral groove, runs in towards the mouth region from these three arms. Two further ridges, possibly representing the suture between the adambulacral and infero-marginal plates, border the ambulacral " groove " in the north and north-west arms. Rather indistinct traces of rectangular infero-marginal plates can be made out on the left side of the north-west arm. In so far as it is possible to assign this specimen to any described genus of starfish, it seems to resemble *Calliderma* Gray more closely than other figured types.

The finding of the starfish has naturally excited interest amongst the mine-workers, but so far no further fossils have been found, despite a very considerable weekly output of sand. Hence it is inviting to speculate on this solitary starfish, and an examination of the sand grains seemed worth while.

The purity of the sandstone is quite exceptional. Heavy minerals are almost non-existent ; I have seen only occasional ragged flakes of white mica, one crystal of tourmaline, several rounded and polished grains of limonite, and a black opaque mineral. The quartz grains include an occasional rose-quartz. Bearing in mind the aeolian qualities of this sand elsewhere, similarities may well be expected here. When the grains are examined dry, there is no trace of wind action. The quartz grains have a clear glassy lustre, their moderate rounding is due to conchoidal fracture, and many bear undamaged crystal facets and little pyramids. When, however, the grains are mounted in Canada Balsam, facets and angular edges " disappear ", and the grains appear to be perfectly rounded and have frosted surfaces. Practically every grain has an irregular deposit of water-clear secondary silica, and each one examined, down to 0·15 mm., is a millet seed with frosted surface.

The grains are well graded ; roughly 46 per cent is about 0·29 mm. or slightly more, and 42 per cent lies between 0·25 and 0·21 mm. Although dust seems abundant there is only 0·8 per cent of the total weight under 0·15 mm.

Wind has obviously played an important role in the formation of this sandstone. Silicification probably occurred at a later date, when

the chalk of Beinn Iadain was silicified. It may be normally supposed that the starfish gives definite proof that the sandstone was finally deposited in water ; and certainly the presence of mica flakes and a proportion of silica dust might seem to support this theory. An element of doubt must still be present, nevertheless, for not merely can a little fine material be trapped in desert sands (perhaps when the winds are gentle for a period) but a starfish, stranded by the tide, can be blown up the beach. It is possible that this starfish, preserved as an impression, without calcareous plates but with carbonaceous material associated, may have been mummified in sand just above sea-level.

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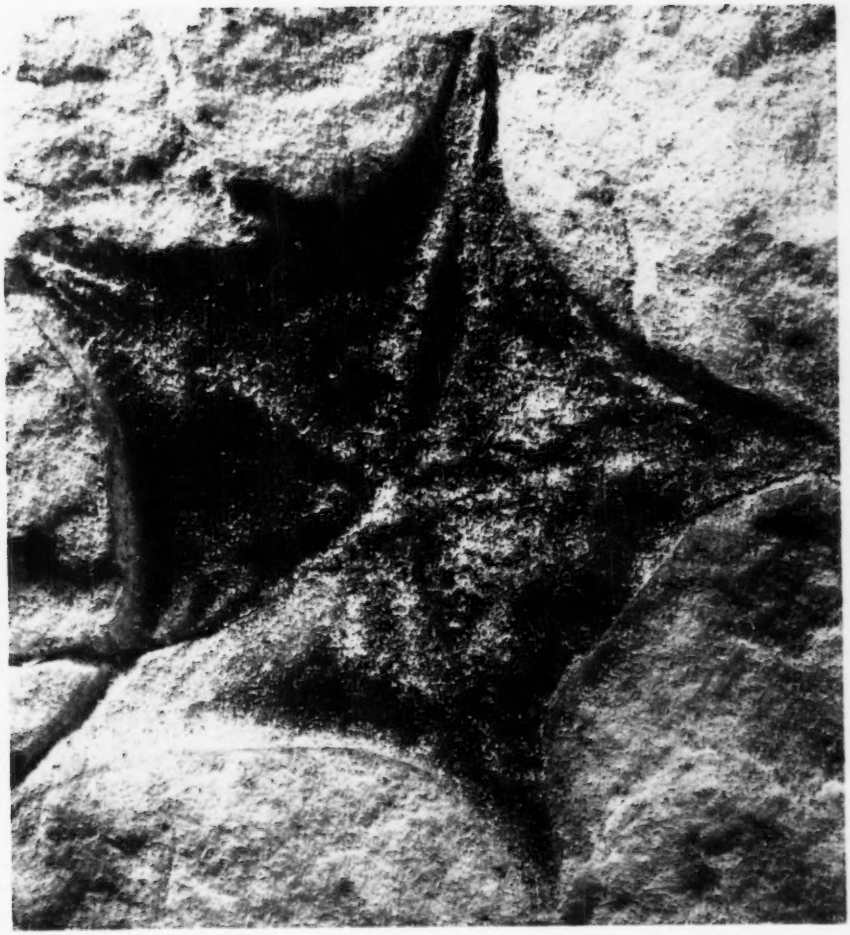
PLATE DESCRIPTION

The starfish preserved as an impression of the actinal surface in the Loch Aline glass sand. Almost flat lighting has been used, slightly stronger from the north-west to bring out the details. The relief is not so strong as the photograph suggests ; it is partly emphasized by the traces of carbonaceous discoloration. $\times \frac{8}{9}$.



A STARFISH FROM THE GLASS SAND OF LOCH ALINE.

Notes on the Nile Valley in Berber and Dongola

By K. S. Sandford

Abstract

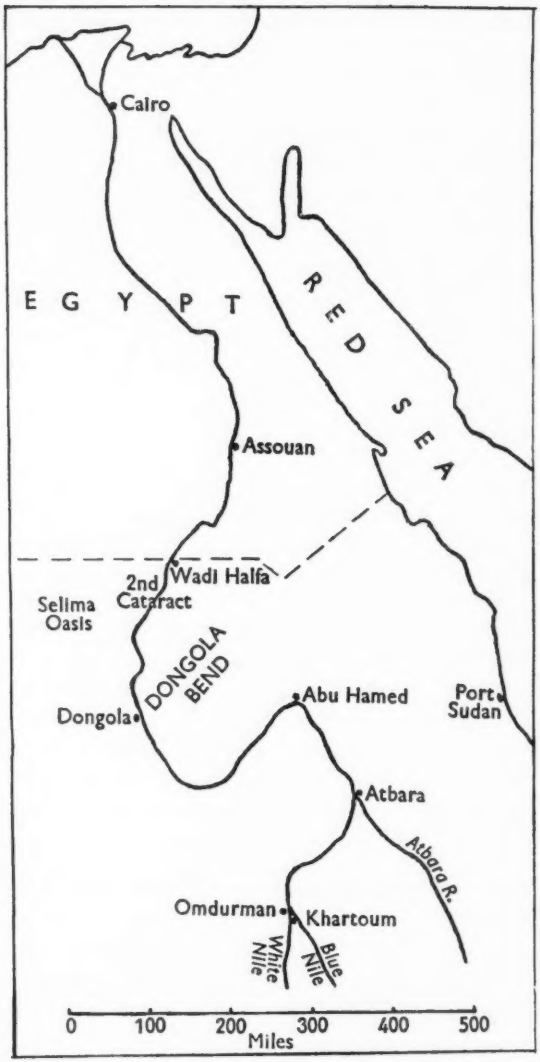
Low-lying physiographical features in the northern Sudan are associated with Lower Tertiary " lake beds ". Some undulation may have been imposed, e.g. in the Dongola bend of the Nile. There has been little vertical river erosion below the level of the lake beds in the northern Sudan, whereas in Egypt there were long successions of Tertiary sediments, uplifts, folding, and faulting. Neither late-Tertiary marine flooding nor successive regradings of the Nile in Egypt reached the Sudan. With reference to the present flood plain the summit level of some silts of Palaeolithic age rises in a striking manner from the country around Atbara (and probably a wider area) downstream into the Dongola bend, reaches a maximum (so far as known) around Wadi Halfa, and then falls again.

Introduction

FIELD work was done around Atbara and Merowe, between Shendi and Dongola, late in 1932, and at the time it was likely that it would be extended. Only passing reference was made, therefore, to the results (Sandford, 1933 (a) and (b), 1936 (b)). In 1935 some notes on the work were sent to the Director of the Oriental Institute, University of Chicago, the late Dr. Breasted, who had enabled me to carry out these and other field studies, and to the Government Geologist, Khartoum. They were a temporary measure, to serve until another field season might be possible, but the war intervened, and the following observations are published so that the information may be available to later investigators. For advice on the field work, for available information and for facilities in the field I am indebted to Mr. G. W. Grabham, who was Government Geologist at the time.

Physiography, and Lower Tertiary Lake Beds

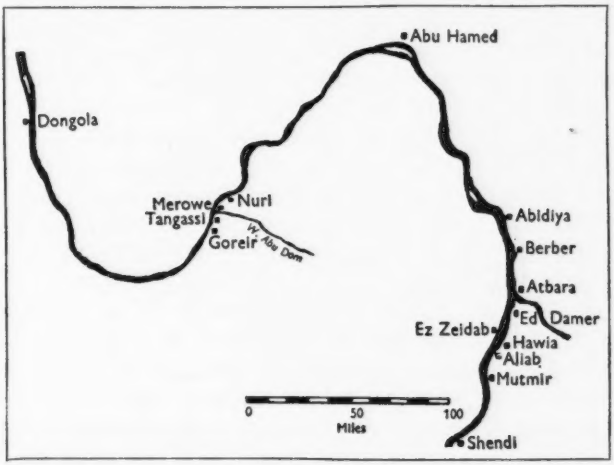
Approximately from Khartoum to Assouan (Text-fig. 1) the Nile flows through regions of Granite—gneiss—schist complex and " Nubian Sandstone " : the former give rise to broken water and cataracts, the latter mark more lethargic reaches of the river's course. In some parts, therefore, the river is engaged in active erosion of its bed in the ancient complex, imprisoned between walls of the overlying sandstones, but elsewhere it seems to have been long adjusted to the Nubian beds. Thus, its course is only about 30 metres (100 feet) below the top of some of the Lower Tertiary sediments, probably lacustrine, which lie on Nubian strata in the country around Atbara (Cox, 1932, 1933 ; Sandford, 1933 (a) ; Andrew and Karkanis, 1945). The dispositon of these Tertiary beds and physiographical evidence over a wide area led me some years ago to suppose that there are two groups of surfaces



TEXT-FIG. 1.—The Nile valley north of Khartoum.

in the northern Sudan : (1) higher, post-Nubian surfaces, represented by many isolated hills between the northern French Equatorial Africa and the Nile, locally capped with basalt ; (2) lower plains, also with basalt flows, fretting the higher tablelands, Lower Tertiary to Recent around Atbara and other riverine districts, and including much of the southern Libyan desert, which has also been modified by wind erosion.

Much work remains to be done, but it might be a fair approximation to say that the highlands are generally 600, 800 m. (about 1,970, 2,625 feet),[1] and more above sea-level, and the lower plains usually within 50 m. (164 feet) of the 400 m. (1,312 feet) contour. Andrew (Andrew and Karkanis, 1945), dealing with the chert bed of the Lower Tertiary deposits around Atbara, concludes that the lake was perhaps 500 km. (about 310 miles) wide from east to west, and 250 km. (155 miles) from north to south, and that the existence of a broad



TEXT-FIG. 2.—The Nile valley in Berber and Dongola.

plain in the northern Sudan is suggested by the disposition of the chert. Quoting G. Y. Karkanis' section on J. Nakhara, near Berber (Text-fig. 2) he shows that the lake beds are capped with basalt and remarks that the events which he describes probably preceded much of the vulcanicity, although the age of the lavas on J. Nakhara is not precisely known.

The impression that the Nile has achieved little vertical erosion in the northern Sudan, except in the cataracts, since Lower Tertiary times is strengthened by the study of gravels in the Atbara–Berber district (below), and by the discovery of Lower Palaeolithic implements in gravels about 5 m. (16 feet) above flood plain in Khor Abu Anga, 1 km. (0·62 mile) downstream of the Blue and White Nile confluence at Omdurman (Andrew and Arkell, 1943). The implements occur in ironstone gravels which, it is claimed, are of sedimentary detrital origin. They may well be so, but their value as a negation of previous

[1] All measurements from maps are given first in metres (followed by conversions into feet). Measurements in the field were made with an Abney level and are given in feet, followed by conversion to metric system.

views (Sandford, 1935) on the presence of lateritic " marram " (or pea iron ore) in the southern Libyan desert is a matter of opinion. I indicated many years ago (1936 (a)) that the period of " lateritic " climate was early and has not recurred, and such cappings are demonstrable in the areas in which they were mapped. An important paper by J. M. Edmonds (1942) concerning areas much farther south does not disprove the reality of a former climate suitable for their production : the pea iron ore may suggest rather, as do other types of evidence, (Sandford, 1936 (a)), that minor changes of climate may produce major changes of environment in a remote continental interior (Grabham, 1926), and that in the broad desert fringe of the northern and western Sudan, refinement of physiographical subdivision will be possible.

Negative evidence that the Nile has achieved little vertical erosion in the northern Sudan lies in the failure to find high level river terraces south of the Dongola bend. Flat-topped ridges in the Berber–Shendi district, especially on the west side of the river, simulate river platforms, but probably owe their contours to the bedding of the Nubian beds : the Lower Tertiary deposits occur on some of them (e.g. Ez Zeidab and J. Nakhara). Denudation of conglomerates in the Nubian beds provides gravels which may be deceptively like river gravels, but Grabham had pointed out that pebbles of agate and cherts, derived from the Lower Tertiary beds, indicate true Nilotic material ; he found them to be prominent (as much as 20 per cent of a sample) and noted them as far north as Wadi Halfa. They occur as far north as Cairo (Cox, 1933, p. 325). Nile terraces 300, 200, and 150 feet (91, 61, and 46 m.) above the river appear north of the Dongola bend and may be traced northward : Lower Palaeolithic terrace gravels are 100 feet (30 m.) above the Nile throughout Egypt.

There seems, therefore, to be a marked dissimilarity between the Nile valley upstream and downstream of the Dongola bend, so far as the altitudes of terraces and gravels, and even their occurrences, are concerned. Continuity is maintained round the great bend by some remarkable silts which, with patches of gravel beneath them, will now be described.

Old Nile Gravels and Silts and Their Ages

Nilotic gravels occur in several forms, of which two should be noted : (*a*) genuine gravels, well graded or with a certain amount of interstitial sand ; (*b*) wind-denuded concentrates of pebbles, usually small, from considerable thicknesses of silt. The latter may form prominent banks which are not, in fact, original features. Study of some 100 km. (62 miles) of the east bank, about 50 km. (31 miles) to the south and north of Atbara, and around Ez Zeidab, on the west bank, amplified

what Grabham had already observed in the field notes which he put at my disposal, namely that genuine Nilotic gravels rise to about 25 feet (8 m.) above flood plain in that stretch of the river. No fauna nor human implements were found in them. Local detail, with which these notes are not primarily concerned, can be seen south of Aliab, near Mutmir ; north of Aliab, near Hawia, west of Ez Zeidab ; Ed Damer (where pebbles of the chert are prominent) ; from Atbara, through Berber, to Abidiya (with chert sometimes abundant).

In several places they clearly pass under old silts, and at two localities, Atbara and Abidiya, instructive sections were exposed. At Atbara, gravel, forming ridges east of the town and of the aerodrome, slopes gently toward the Nile and passes under old silt : the gravel consists largely of quartz pebbles, with some of the chert, and its upper limit seemed to be 24–26 feet (8 m.) above flood plain. The continuity of the gravel below the silt was traced in a number of pits and small exposures (e.g. E.N.E. and S. of the merkaz, immediately north of the hospital, on the golf links, to the river bank). The recent alluvium of the flood plain is seen at the foot of the old silt along the river bank ; and the old silt either slopes gently to the flood plain or presents a cliff of about 5 feet (1½ m.) on the one hand, and on the other thins out at about 10 feet (3 m.) above flood plain on the rising surface of the gravels.

The best section was seen in pits on the north of the hospital (Text-fig. 3) :—

3. Old silt, conforming to bedding of gravel below and filling hollows in its variable deposition : occasional strings of fine gravel : lime concretions : some gasteropods, c.f. *Melanoides*, and *Aetheria* (" Nile oyster "). Maximum of 5 feet (1½ m.).
2. Fine well-bedded gravel with rolled and unrolled *Aetheria*, some in position of growth. Middle Palaeolithic implements in place in these gravels more than 5 feet from top of section. Thickness as much as 12–15 feet (*c.* 4–5 m.).
1. Seams of coarse gravel, pebbles *c.* 6 cm. diameter, and subangular pebbles of the Lower Tertiary chert, in sandy silt with concretions : one indeterminate mineralized bone fragment. No implements. Maximum of 10 feet (3 m.). Lower beds salty and base of pit waterlogged at time of visit (December).

The average depth of section was about 12 feet (4 m.).

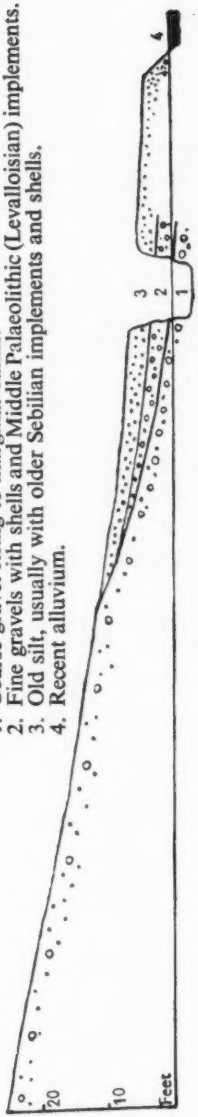
Bed 1 is identified with the exposed gravel ridges of 24–26 feet (8 m.), and the various sections made clear that part of a cross-section of an old Nile bed is exposed, in which Bed 2 overlaps Bed 1 and is in turn overlapped by Bed 3 : but the last does not attain the height of the marginal gravels which pass down into Bed 1.

As far as I know this was the initial discovery of Middle Palaeolithic

or Levalloisian (Caton-Thompson, 1946) implements *in situ* in bedded gravels in this part of the Sudan : it was the result of J. H. Dunbar finding a specimen on the golf course.

North of Atbara the gravel ridges appear again around Berber and, as elsewhere, seem to sink stratigraphically below the old silt, with much erosional downwash over it : they are seen again north of the town, where Grabham recorded them to about 5 m. (16 feet) above the old silt, i.e. about 9 m. (30 feet) above flood plain.

Farther north, at Abidiya, the coarse gravel forms a ridge 1½ km. (0·9 mile) to the east, and sinks toward the river beneath the old silt. At the river bank coarse, highly polished, hard-set gravel is seen in a prominent bank, and polished Middle Palaeolithic implements are associated with it. The top of the coarse gravel coincides with the modern flood plain water mark (there being no alluvium at this point), and in my opinion it is a continuation of the eastern ridges under the same circumstances as at Atbara. Grabham records pebbles to 10 cm. diameter at the station (river bank). The old silt mounts to about 14 feet (4½ m.) above flood plain here, and the gravel ridges rather higher.



TEXT-FIG. 3.—Sketch section of gravels at Atbara.

From these records it seems clear that in the 100 km. (62 miles) reach of the Nile described above old Nile gravels rise to a marginal height of 24–30 feet (7–9 m.) above flood plain, but no implements have yet been found in them : their continuation is traced in cross-section, and they are followed there by gravels containing Middle Palaeolithic (Levalloisian) flakes.

Everywhere such gravels are covered by old silt, the upper limit of which is above the reach of any present Nile flood : it is irrigated

locally by pumps and is a prominent feature along the Nile, sometimes forming wide plains and providing the bed of the rail track over long distances.

Thus, from the south of Aliab to the mouth of the Atbara River there are considerable plains to about 10 feet (3 m.) above flood plain east of the Nile, and the silt occurs similarly on the west bank around Ez Zeidab. Sections are fairly numerous, especially in shallow cuttings along the railway. For example, at Ed Damer sandy silts with fine quartz gravels are exposed, and can be traced eastward, where the contemporary river course seems to have lain. Palaeolithic implements of older Sebilian type, i.e. known in Egypt to be stratigraphically and typologically younger than the Middle Palaeolithic (Levalloisian) flakes already mentioned, are conspicuous features not only on the surface of the silts around Ed Damer and throughout the 100 km. (62 miles) of river bank here described, but they occur *in situ* in the silts themselves.

The silts, with their implements, are well seen north of the mouth of the Atbara River, with summit levels approximately 10–14 feet (*c.* 3–4 m.) above flood plain : Berber is built on them : there are extensive plains around Abidiya : everywhere the silts are characterized by small concretionary lime pellets. They may be seen at intervals, with the same features, northward to Abu Hamed and into the region of cataracts downstream of it, and for this reason the deposits were sought in the Dongola bend of the Nile, on the left bank, up- and down-stream of Merowe. A special problem was presented here by the entrance of a tributary, the wadi Abu Dom which, though normally dry, flushes occasionally, and I was invited by Mr. Grabham to look into the resulting conditions.

It was evident that the old silt constituted a prominent feature, and that it contained older Sebilian implements, lime pellets, small polished pebbly gravel, pebbles of Lower Tertiary chert, as in the country around Berber. It is, in fact, displayed in dusty plains with cliffs, and is much dug over for some miles upstream of Merowe, forming a marked topographic feature at a general level of about 20 feet (6 m.) above flood plain. But close inspection shows that the deposits rise to 55 feet (17 m.) above flood plain, especially in the district of Nuri, where they form a marked upper platform. A typical section here is :—

4.	Mud and pebbly surface,	10 feet	(3 m.)
3.	Grit cemented by lime, with casts suggesting reed stems,	4 feet	(1 m.)
2.	Polished gravel and sand, travertine,	10 feet	(3 m.)
1.	" Lake beds " with sticks, mud, and travertine ; *Aetheria*. Rolled implements marked here and in underlying interdigitating gravel : exposed,	10 feet	(3 m.)

Remainder of section above flood plain concealed.

It might be supposed that the high level of the silt was due to damming by an incoming tributary (the Abu Dom). Indeed, large sums have been spent on training works to deflect its occasional flood waters from Merowe and to reduce damage to land. The floods have destroyed the works, nevertheless, and recent thick accumulation has taken place round some of them only to be eroded by subsequent torrents : the wadi breaks through the full thickness of the old silts. A traverse immediately on its downstream side revealed first a low-lying, partly irrigated mud-flat, largely silt derived from the Abu Dom. The old silt can then be traced to a height of 36 feet (11 m.) above flood plain, with a flat of 20 feet (6 m.). Much of the ground has been dug over and it is clear that the silt is typically Nilotic, and not a product of the wadi ; it contains the usual pebbles, lime pellets, reed-like tubes, rolled and unrolled older Sebilian implements, and it is locally cemented by lime. Beside the wadi, gravel moved during spates, containing pebbles of pumice derived from a volcanic area in its upper course, lies on the white pellet and silt beds.

Downstream of the Abu Dom's mouth, near the ruins of the pyramids of Tangassi, there are low gravel mounds, with rolled implements of the same type as those in the silt, and patches of coarse Nilotic gravel with pebbles of Lower Tertiary chert : they are to be distinguished here from other gravel ridges which are no more than Nubian quartz pebble beds *in situ*. Finally, at Goreir, a little further downstream, an isolated ridge (visited at the pumps) proved to be 55 feet (17 m.) above flood plain. It consists of sandy river silt, with small pebbles concentrated near the top, is full of concretions of lime and sticks, contains some freshwater shells (species of *Corbicula* and *Unio* were noted) and fragments of black bone. Older Sebilian implements occur in sandy silt at and near the top, mostly on the slopes, and in fine beds. Pebbles of pumice from the Abu Dom are included.

From here upstream to Nuri there is a mud flat about 3 feet (1 m.) above flood plain, sometimes wide, marking deposition after extensive vertical erosion : the newer silt resembles the old but contains only very small limy bodies, often none at all, and no stone implements were found in it.

The following conclusions may be made from the field work in the Merowe district :—

1. The incoming of the wadi Abu Dom did not pond up the river effectively, because the old silt is found at the same height above flood plain both up- and downstream of its mouth.
2. The silt is identified as the same as that in the district around Atbara, but its altitude above flood plain is much greater. As around Atbara, it descends at any rate as low as present flood plain levels.

3. The gravels with Middle Palaeolithic (Levalloisian) flakes around Atbara (beneath the silts there) are not yet identified around Merowe, nor are the coarse gravels without implements.

The negative evidence is probably unimportant, because my visit occupied only two or three days, and much detailed field work remains to be done.

4. The upper parts of the silts around Merowe are represented by isolated ridges and hummocks, there has been much erosion, and the platform occasionally at about 20 feet (6 m.) is probably no more than a stage of denudation, possibly due to concentration of sand and small pebbles by wind erosion at this point: dust, blown from the silt, particularly where the surface is broken, is extensive.
5. The low-lying silt surface, at about 3 feet (1 m.) above flood plain is a feature of some interest; it may or may not be identifiable with the usual expanses of low-lying alluvium along the Nile and Atbara River, and its relationships to a Nile channel, now buried, such as has been proved at Khartoum (Andrews, 1912), and to deposits of the Blue Nile (Grabham, 1938) are unknown.

The most significant result, coupled with the finding of implements in the deposits, is the indication that with reference to the present flood plain as datum, the general upper level of the old silts rises downstream, coupled with the fact that in the Second Cataract and around Wadi Halfa the silt, with the same assemblage of implements, lime pellets, and fossils (so far as known), reaches a height of 100 feet (30 m.), and then falls steadily northward till it passes beneath the present flood plain in Middle Egypt. It is therefore an important unit in the study of the river from Khartoum to Cairo.

Moreover, so far as I know, the silts and some accompanying gravels are the oldest alluvial deposits of the Nile within the Dongola bend, and I am reminded of an impression—it is no more—gained in the field some years ago, particularly between Selima oasis and the Nile, that formerly the course of the river lay to the west of the present region of cataracts upstream of Wadi Halfa, and it is possible that the higher terraces may be found there. I had hoped to continue these studies in which my wife had taken part, downstream from Merowe; and to traverse the country, particularly on the west side, in a field season which is now, perhaps, unlikely to take place.

The Old Silts as a Physical Problem of Nile Hydrology

The implications of the observations around Atbara and Merowe on river studies upstream along the Atbara River, along the Nile to Omdurman, and in the Gezira (between the Blue and the White Nile), can be omitted from these notes because they are at the moment mainly of interest within the Sudan, where they can be related to the

review by Andrew (1944) contained in the Soil Conservation Committee's Report.[1] Moreover, a contrast of climate and river history in the plains and cataracts of the northern Sudan with those of Upper, Middle, and Lower Egypt has already been analysed elsewhere (Sandford, 1936).

But so far as the Nile is concerned the African climate is indeed an obvious intrinsic factor, because it governs run-off, velocity, and volume of the river and its tributaries ; there are striking evidences of changes from the transportation of coarse material to the movement of little more than silt, such as is carried to-day.

How, then, is the peculiar behaviour of the old silt from the region of Atbara (and farther south) northward into Egypt to be explained ? It appears to be the product of a circumscribed event, with essentially similar lithology, human implements, and (probably) fauna throughout its distribution. Perhaps it is significant that it is comparatively low-lying in the lowlands upstream of the Dongola bend, where maybe, there was plenty of room for it. It rises in the locally restricted courses of the Dongola bend and reaches its greatest known thickness and height above present flood plain at and near the exit from the difficult region of the Second Cataract, at Wadi Halfa where, again locally, there was plenty of room for it. Its steady fall thence northward might be related to the ultimate base level of the Mediterranean.

It is unlikely that the velocity of the silt-bearing waters differed appreciably from that of the Nile flood of to-day : if it had been much greater substantial gravels would have been formed, which generally is not the case : if it had been much less, mud in suspension might have been moved, but the sand and grit, dependent on velocity, might be hard to explain. The accumulation is most extensive where the available depositional area was broadest, i.e. much of the silt was swept into embayments and backwaters.

In short, the material was the aggraded product of a silt-carrying river, in a part of its course which was remote from any effect of a change in an ultimate base level. It could be explained by a depression of the Dongola bend—the river grade remaining much as it is to-day and the deposit being thickest where depression was greatest : but there seems to be no other evidence to support such a suggestion, nor would it account for high-lying silt in Egypt. Increased run-off would involve increased velocity in restricted cross-sections with a deeper river : decreased run-off for a given load might lead to aggradation and is in harmony with the general tendency of contemporary climate of the region, so far as known ; increased load for

[1] See also J. D. Tothill, The Origin of the Sudan Gezira Clay Plain, *Sudan Notes and Records*, XXVII, 1946, pp. 153–184, which has come to my notice after the text went to press.

a given velocity would have a similar effect. In the Atbara, Blue, and White Nile basins lie inexhaustable reserves of load, and unknown past changes in régime.

One thing seems certain : the silt is clearly similar to material which the Nile carries to-day, even if it is not so fine, and provisionally it can be judged by the same standards ; if the facts set out in these notes are correct, they can be regarded as a physical problem of Nile hydrology.

To conclude, the views set out above must be compared with those expressed by the late Dr. John Ball (1939). It would be proper to explain that I kept him posted with all available unpublished results while he was writing his book and we had opportunities to discuss some parts of it.

So far as continental stability is concerned he and I arrived at much the same conclusions by somewhat different means for all the Nilotic deposits except the low-lying beds : these he thought to be related to an isolated eastern Mediterranean, and such may have been the case. With regard to the profile of the older Sebilian silt, descending northward from 100 feet (30 m.) above flood plain at Wadi Halfa, the situation is more difficult. Ball suggested that the exceptional slope was the result of a temporary increase in the silt-content of the Nile, as a consequence of the tapping of a great lake south of Khartoum (Lake Sudd). I do not propose to discuss the hypothesis, which introduces many acutely difficult problems and unknown factors, but I believe Ball was impressed primarily by the fall from Wadi Halfa northward (as his text-figure shows), and that he did not fully appreciate that the old silt is only some 10 feet (3 m.) above flood plain around the mouth of the Atbara River, and south of it, that it rises slightly toward Abu Hamed, and strongly in the upstream end of the Dongola bend, as I have shown in these notes. The essential character, as I see it, is the rise downstream in that region, and the fall northward from Wadi Halfa, a character which I believe to be original and not the result of subsequent localized bed erosion, providing an exaggerated view of a rise of the top of the silts : the old deposits descend into the present channel and their base is rarely seen, so a channel had been cut, it was filled with silt, and through the silt the river has lowered its course.

Pliocene Marine Beds and Later River Deposits as Evidence of Continental Stability

In Egypt three stages must be contemplated, and in their broadest terms they are as follows :—

(1) Cretaceous to Miocene marine sedimentation, including Upper Eocene–Oligocene freshwater beds : mainly the products of a broad sea retreating northward. Most of the sediments are still flat-lying.

(2) Pre- and post-Miocene general elevation, faulting, and flexures, *mainly* along N.–S. and N.E.–S.W. lines (Hume, 1930).

(3) Late Miocene to present-day land surfaces with (Pontic) cutting of a deep Nile valley and tributaries, subsequent various phases of filling up and re-excavation.

From (1) it follows that the presence of a supposed *Pinna* (Cox, 1933) in the Lower Tertiary lacustrine beds (with strong probability of Upper Eocene or Lower Oligocene age) around Atbara is not so improbable as it at first appears : i.e. *Pinna* is a marine form. Problems arise about the northward recession of scarps cut in the Cretaceous and younger marine sediments.

From (2) it should be observed that the country inside the Dongola bend is regarded as an anticlinal undulation, which the river has had to negotiate. It is logical to conclude, but it is not proved, that the surfaces with which the Lower Tertiary lake beds were related have been warped here. Was there further movement when the river cut its course, subsequently silt-filled and re-excavated, and has this any bearing on a supposition that the river had a course west of the cataracts ? I am aware of no concrete evidence.

With regard to (3), whatever differential movements there were in Tertiary times, in the Pliocene the Pontic gorge-like Nile valley in Egypt was flooded by the Mediterranean, and the summit level of the deposits, which are of unknown thickness, has maintained its horizontality somewhat below the 200 m. (650 feet) contour from end to end of the flooded valley. In southernmost Egypt and the northern Sudan there was no such gorge and there are no similar deposits, and it follows that the relief associated with the Lower Tertiary lake beds may have stood not greatly above the summit level of the Pliocene gulf.

The importance of the horizontal summit level of the Pliocene beds—and only about the apex of the Delta are isolated Nile gravel patches found above them—lies in the implication that subsequent changes of river level, represented by terraces and aggraded and degraded valley fillings (with the exception of the old silt described above) have been governed by an extrinsic factor, namely relative changes of level between the continental mass and Mediterranean sea levels. That implies that they have been influenced little, if at all, by differential movement in the coastal regions. Moreover, the older and higher terraces seem to fail in the south, and such Lower and Middle Palaeolithic gravels of the Nile as are yet known there are low-lying : thus, in the continental mass the region of greatest river activity, in the vertical plane, lies nearest the sea and the performance of the Nile might be regarded as a yard-stick by which relative changes of level between Mediterranean and stable Late Tertiary to Recent north-east

Africa might be accurately measured. The disappearance upstream of certain aggrading and degrading phases might give some indication of the duration of these phases.

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Accuracy in Geological Place-names

By R. H. Rastall

Abstract

In the interests of accuracy and practical convenience, a detailed account is given of several instances well known to the author where vague or badly chosen place-names have given rise to uncertainty or even definite errors, in the position of geological localities, including one recent description of an important deep boring in N.E. Yorkshire. Attention is also drawn to an increasing looseness in the definition of the ancient local name of Cleveland. Trouble has also been caused by the recent invention of a new place-name, Ravenscar, which is synonymous with the ancient name, Peak (not The Peak, as often written by geologists). When an author is not himself thoroughly conversant with the place-names of his district it is recommended that some local authority, not necessarily a geologist, should be consulted.

As a corollary to a recent appeal by Mr. Percy Evans for greater precision in the use of geological maps, I venture to set forth some examples, derived from personal experience, in which the employment of badly chosen or imperfectly defined place-names has led to trouble or ambiguity. These examples are all chosen from my native district of North-East Yorkshire, which, of course, I know best in detail, which possesses a very large geological literature, and is in reality a classical area in stratigraphical geology, as witness for example William Smith's geological map of Hackness.

In this district there are two recent deep bores, which have lately been described in considerable detail. The name of the older of them has now, I think, definitely settled down as Aislaby, after a false start. It was at first described as in Eskdale, which was true, but much too vague, as Eskdale is a valley 20 miles long. It also led to the unfortunate result that in at least one publication of the Geological Society of London the bore was referred to as " at Eskdale " which, of course, is ridiculous. The site of the bore is actually about a mile from the village of Aislaby and as there are two villages of that name, about 20 miles apart, a perfectly correct and suitable description would be " Aislaby in Eskdale ".

The case of the other boring is more difficult. It is officially referred to in the literature as in the Cleveland Hills, which is altogether too vague to help anyone who does not know beforehand where it actually is. The site is a little to the west of Bilsdale, which is a very long valley and the nearest place with a definite name is Chop Gate, pronounced Chop Yat, which is a tiny hamlet consisting of little more than an inn, long famous for " real Yorkshire ham-and-egg teas ". However, this name would have been fairly well adapted for the bore, as at least giving an approximate position findable on a map.

Now the use of the term Cleveland Hills itself involves many

difficulties, partly due to the considerable extent of the said hills, partly to the want of any authoritative definition of them, and partly to a gradual change in the application of the name Cleveland in geological literature. Taking the last point first, the trouble seems to have begun with Professor Kendall's classical paper on Glacial Lakes in the Cleveland Hills, because only a very small proportion of the country covered by that paper can possibly be described as in the Cleveland Hills. Nevertheless many geologists without local knowledge got the impression that Cleveland includes the whole of the moorland area, east to Scarborough and south to Pickering and Helmsley. It is a misfortune that the old name " Blackmoor " for the southern half of this region has entirely gone out of use. I have not heard it spoken for over fifty years. If still current it could have been extremely useful in geology.

A strict definition of Cleveland is not easy for the general reader. It is probable that the best delimitation can be obtained from the map in Ord's *History of Cleveland* (1843). Although this book contains many errors, historical and otherwise, the author presumably knew the boundaries of his area. Two points of importance are quite clear : the eastern boundary of Cleveland is at Eastrow Beck, about three miles west of Whitby, while the southern boundary is the Esk-Rye watershed westwards from about Goathland. This leads to the curious paradox that only half of the anticlinal Cleveland uplift is in Cleveland, as the watershed is the crest of this uplift. When interpreted strictly according to this criterion it turns out that the Cleveland Hills boring is not in Cleveland, being slightly south of the watershed.

Now as to the definition of the actual Cleveland Hills there is much discrepancy of opinion, and in most published maps there is something to object to. Even in the most recent publication of all, the Regional Handbook of the Geological Survey on *East Yorkshire and Lincolnshire*, in some of the maps the name Cleveland Hills is so placed as to exclude their most typical, characteristic, and spectacular feature, Roseberry Topping—the Othenesberg of the Norsemen who first named their *Cliff-land*, which name (= Odin's Hill) shows what *they* thought of it. The Norse name Cliff-land at any rate seems to imply that the Cleveland Hills extend to the sea, where Boulby Cliff, the highest on the English coast, towers over everything else, in spite of great damage from alum workings.

Another very common error, which it seems impossible to eradicate, in spite of repeated protests is writing " The Peak " for Peak, between Robin Hood's Bay and Scarborough. The name Ravenscar, which is practically synonymous, is in reality a modern fake, due either to a land company or the North-Eastern Railway. The name Blea Wyke simply means " blue creek " and an early author who received a severe

snub from authority for writing " Blue Wick " was in reality perfectly correct, *wick* and *wyke* being synonymous. People who know this coast derive much amusement from twaddle about Vikings as sea-kings : the word simply means " dwellers in the creeks ", and has nothing to do with any sort of king. But this is not geology.

Now the object of all this discussion of local detail, which readers, if any there are, will probably find tiresome, is just to suggest that authors writing papers and choosing place-names in districts that they do not know intimately, would as a rule do well to consult some local authority, not necessarily a geologist, as to such choice and definitions, as there are many pitfalls in local names. I do not for a moment suggest that the district here discussed is worse off than many others in this respect.

Finally a very brief but pointed anecdote : a museum palaeontologist once gave the locality of a fossil, without any place-name, as " four miles north of Ribblesdale ". Surely he took the prize for vagueness. As Ribblesdale is about forty miles long and runs north and south, further comment is hardly necessary. People in the south of England do not seem to know what a *dale* is.

Ranikothalia in East and West Indies

By L. M. Davies (Grant Institute of Geology, University of Edinburgh)

Abstract

The author emphasizes the distinction of the marine Paleocene fauna of India from that of Europe, and its resemblance to that of the West Indies (Antilles). He suggests a marine connection between West and East Indies across North Africa, south of the Mediterranean region, in basal Tertiary times, before the Americas had drifted far from Europe and Africa.

The Indian Paleocene Fauna

It is a striking fact that while the Maestrichtian (or Dunghan, *s. str.*) foraminiferal fauna of North-West India definitely corresponds with that of western Europe (*cf.* L. M. Davies, 1941), and while the Lutetian (or Kirthar) fauna of North-West India again closely resembles that of Europe, the intermediate Paleocene (or Ranikot) fauna of North-West India is very different from its contemporary counterpart of the Mediterranean region (*cf.* L. M. Davies, 1927, 1937, 1940). This seems to indicate that, after losing its contact with European waters during the great marine regression of Danian times (marked by the Hangu Sandstone of North-West India ; *cf.* L. M. Davies, 1930, p. 9 ; 1943, p. 65 ; etc.), the Indian region did not regain that contact until after the Paleocene—during which its communications were with some other region, or regions.

Nummulites nuttalli and its Allies

It is therefore worth noting that the most important member of the Indian Paleocene foraminiferal assemblage is the species *Nummulites nuttalli*/*N. thalicus*, which is extremely variable, and merges into *Operculinoides sindensis*/*O. gwynae* on the one hand, and into *Miscellanea stampi*/*M. miscella* on the other (*cf.* L. M. Davies, 1937, pp. 40–42 ; etc.). I was not, therefore, surprised when *N. nuttalli* was adopted by Dr. C. M. B. Caudri (1943–44, pp. 17 ff.) as the type for her intermediate genus *Ranikothalia*, which she erected to link ordinary *Nummulites* (*Camerina* auctorum) to *Miscellanea* (Pfender, 1934, p. 231 ff.).

Affinities with West Indian Paleocene Types

What is more, Caudri herself (*loc. cit.*) and other workers (e.g. Cole, 1944 ; Vaughan, 1945 ; *cf.* Vaughan and Cole, 1941, and H. D. Thomas's remarks, 1946) have emphasized the existence of several species of both *Ranikothalia* and *Miscellanea* in the basal Tertiary beds of the West Indies. Among these western *Ranikothalia* is *R. bermudezi* (Palmer) (1934), which bears a close resemblance to the Indian *N.* (or *R.*) *nuttalli* itself ; and the late Mrs. Palmer told

me (letters of 10th March and 13th August, 1946) that *R. bermudezi* is not a Cretaceous form, as thought when she originally described it, but is a Paleocene one.[1] It therefore not only resembled *N.* (*Ranikothalia*) *nuttalli* but was also its contemporary. As Mrs. Palmer further remarked, there is more resemblance between the foraminiferal faunas of the Antillean and North-West Indian regions in Paleocene deposits than in later ones ; and this fact suggests that there was more direct communication between those regions at the beginning of Tertiary times than existed later. That, in turn, raises the question as to what route the communication took ; since it must have by-passed the Mediterranean region, which was occupied by a different assemblage during the Paleocene.

Togoland *Nummulites*

I was therefore much interested in collections of foraminifera from French West Africa which were sent to me by the Director of Mines at Dakar towards the end of the late war, for I found that while the material from Senegal had a Mediterranean aspect, and was mostly of Eocene age, a small consignment from the vicinity of Toffo (6° 54′ N. : 2° 2′ E.) in Togoland was full of *Nummulites* externally indistinguishable from *N. nuttalli*, and internally also similar—though to a less degree. These cannot be far removed from *N. nuttalli*.

This fact is doubly notable. In the first place, it shows that *Nummulites* appear in West African sediments south of Senegal, a circumstance not hitherto realized (*cf.* A. M. Davies, 1929, p. 316 ; also 1934, vol. ii, p. 101) ; and, in the second place, it affords some sort of link between the East and West Indies. It may be remembered that, according to the theory of Continental Drift, the Antillean region would, in basal Tertiary times, have adjoined the African coast near Togoland (*cf.* du Toit, 1927 ; Gregory, 1929 ; etc.).

Saharan Links with the Paleocene Sea of India

Did, then, communication exist across North Africa to the Indian sea ? Or did the line of communication pass southwards, round the coast of Africa ? There seems, as yet, to be no evidence that the Paleocene sea left similar deposits further south in West Africa ; but collections sent by the Director of the Geological Survey of Nigeria, from Gidan Idaltu (13° 24′ N. : 5° 18′ E.) and Hamma Ali (13° 9′ N. : 5° 18′ E.), near Sokoto and in the latitude of Lake Chad, contain foraminifera which I identified as closely related to *Assilina praespira* Douvillé (1905), and which may be a local variety of the same. This

[1] I see that Caudri (1948, p. 475, footnote 7) reports getting a similar letter (dated 26th March, 1945) from Mrs. Palmer, intimating an Eocene date for *Ranikothalia bermudezi*. But in her rather later letters to me, Mrs. Palmer narrowed matters to the Paleocene.

form is probably the one termed *Operculina canalifera* by A. M. Davies (1934, vol. ii, pp. 74, 112), as also by other workers, whose criterion for distinguishing *Operculina* from *Assilina* differed slightly from my own (1945).

This so-called *O. canalifera* seems to accompany *Plesiolampas saharae* Bather (1904) ; and the latter is significant, since the genus *Plesiolampas* characterizes the Upper Ranikot (late Paleocene) beds of India, and has apparently not been found in European deposits. *P. saharae* has been reported from Gao (16° 16′ N. : 0° 12′ E.), from Tenekart north of Tahoua (14° 57′ N. : 5° 16′ E.), from Tamaské (14° 53′ N. : 5° 49′ E.), from Garadimi (14° 20′ N. : 5° 50′ E.), and from near Zinder (13° 45′ N. : 8° 57′ E.), etc. ; while *P. pacquieri* Lambert (1906) is also found near Gao and Tenekart. As linking these with India, De Lapparent (1903) notes the finding of *Plesiolampas* in Egypt. Moreover, an echinoid described by Gauthier (1901) as *Noetlingia monteili*, of late Cretaceous age and showing Indian affinities, has been found a little south of Bilma (18° 37′ N. : 13° 22′ E.). It seems possible, therefore, that a westward-extending arm of the Indian sea traversed the Saharan region of North Africa in late Cretaceous and basal Tertiary times (*cf.* also De Lapparent, 1901 ; Cottreau, 1908 ; Lambert and Pérébaskine, 1929 ; etc.).

It will be interesting to see if further discoveries tend to confirm this suggestion ; and, in any case, there is no doubt that considerable affinity exists between the Paleocene Nummulitoidea of the East and West Indies, with some apparently linking forms in North-West Africa, a good deal south of the Mediterranean region.

I note that Mme. De Cizancourt now (1948) treats both *Ranikothalia* and *Miscellanea* as synonyms of *Nummulites*, owing to the difficulty of clearly separating these forms in the basal Tertiary beds of the West Indies, much as I emphasize their merging in the Paleocene beds of North-West India. Apparently, this very able worker tends to " lump ", and Caudri and I to " split ", in the matter of terminology, while the facts themselves are unmistakable.[1]

[1] Mme De Cizancourt allows that forms without a marginal cord—and its correlated " canal system "—might be distinguished as *Miscellanea* ; but the final disappearance of that cord is only the last stage in the degeneration of the outer skeleton. The cord still appears, in every intermediate degree, in specimens passing from *Ranikothalia* to the more extreme *Miscellanea*. So note that a very perfect specimen of American *Miscellanea* was figured by Hanzawa (1937, pl. 21, fig. 5) as *P. matleyi*. Observe the complete absence of marginal cord in this individual ; and also the clubbed tops to its pillars—a feature often appearing in Indian *Miscellanea*.

Mme De Cizancourt is emphatic (1948, p. 31) that : " Les Nummulites de la Barbade s'écartent notablement des types habituels, mais par contre possèdent un ensemble remarquable de caractères communs avec les Nummulites du groupe de *N. nuttalli*, du Ranikot des Indes." These latter are, of course, Caudri's *Ranikothalia*.

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Dyke Phenomena of the Dicq Rock, Jersey, C.I.

By M. Casimir and Frederick A. Henson

(PLATE III)

Abstract

The granite of the Dicq Rock is traversed by several veins of fine grained aplogranite. These in turn are cut by a large dolerite dyke, which has been intruded into a brecciated fault zone within the granite. Three large blocks of granite occur within the dolerite ; these originally formed the southern boundary of the fault. The petrography of these rocks, and the influence of the micro-breccia upon the textures found in the marginal and central part of the dolerite, are considered in detail.

Introduction

ALTHOUGH numerous dykes, varying in width from a few inches to over 20 feet occur amongst the igneous rocks of Jersey, they have as yet received little attention. The Rev. C. Noury (1886), in his admirable monograph, devotes a chapter to dykes only, giving a general description of their occurrence. Smith (1933–36) published three papers dealing with the mica lamprophyres only.

The dykes are magnificently exposed along the coast, inland they are well exposed but deeply weathered. It is not unusual to find that dolerite dykes cut aplitic veins, although this is not always the case, and are themselves traversed by the mica lamprophyres. Of special interest is the curious mode of intrusion which some of the dykes exhibit. The aplites and dolerite of the Dicq Rock are here described in detail, their field relationships are shown in Text-fig. 1.

Field Relations

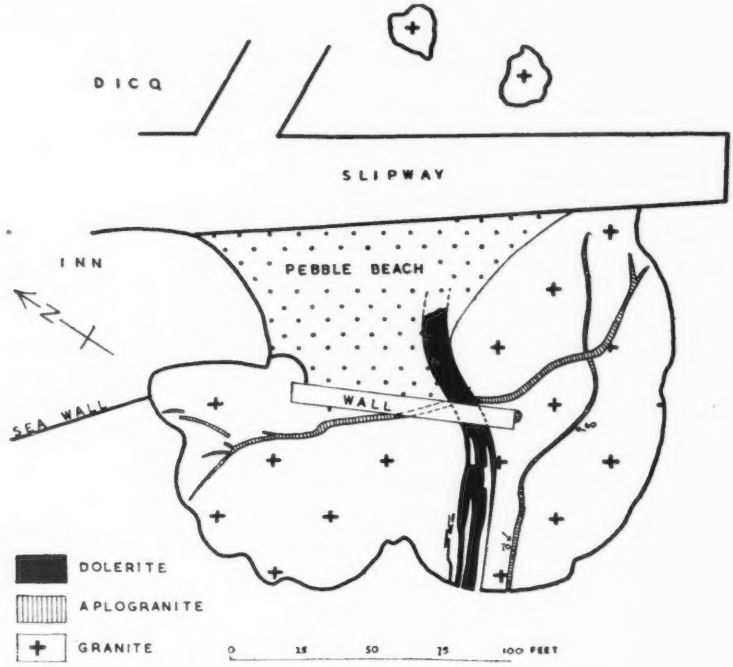
(*a*) *Granite and Aplogranites*

The Dicq Rock, which forms a large topographical feature on the coast south of St. Helier, is situated about 100 yards east of the Havre des Pas Bathing Pool. To the east of Dicq Rock stretches the beach of Greve d'Azette. The dykes concerned intrude a medium-grained porphyritic granite which contains numerous basic xenoliths.

The intrusions consist of aplogranites and a dolerite. The aplites occur both as a vein and, in the case of the later intrusion, as a dyke-like form, thick at its centre and thinning out towards its terminations. The aplogranite dyke and the dolerite intersect at a point beneath the wall (Text-fig. 1), their relative ages have been determined by excavating on the east side of the wall. At a depth of 2 feet the dolerite was revealed and proved to be younger than the aplogranite ; the contact being 13 feet from the south-eastern end of the wall. Six feet east of

the wall the contact between dolerite and country rock was revealed. At spring tides, with heavy seas, the pebble beach shifts and occasionally reveals the dykes.

The aplite vein traverses the granite in an east to west direction and maintains an average width of 7 inches. It has not a straight course ;



TEXT-FIG. 1.—The Dicq Rock, Jersey.

from the seaward end it is traceable eastwards for a distance of approximately 35 yards, tapering off towards the slipway. Viewed from the seaward end it rises to a height of 25 feet and hades to the south at an angle of 70°. The vein continues over the Dicq Rock to the other side, showing up well against the granite, where it inclines 60° north, curves, and is cut by another aplogranite intrusion.

As seen in the field, the contacts with the country rock are not chilled, but are clearly defined. The direction of the aplite dyke is N.W.–S.E. ; its course is irregular and it reaches a maximum thickness of 27 inches. Towards the north-west the dyke makes a sharp bend due west and then resumes its original direction. The dyke gradually diminishes in thickness and tapers out. Small offshoots occur, one showing echelon arrangement.

The south-eastern part of the dyke curves to the east, encloses small fragments of the country rock and cuts the earlier aplogranite vein. After a further distance of 6 yards the dyke bifurcates and tapers out.

(*b*) *Dolerite.*

The field relationships between the dolerite and granites are very clearly displayed. The general direction of the dyke is S.W.–N.E., and it is exposed, up to the wall, for a distance of 20 yards. In the field the contacts with the country rock show no chilled margins ; they are normally well defined and sharp. On the south-eastern boundary, associated with dolerite veins, a micro-breccia occurs.

On the north-western boundary of the dolerite dyke an offshoot of a 9 in. dolerite shows echelon arrangement. Three large granite blocks occur within the main dolerite dyke (Text-fig. 1) ; there can be no doubt that these three blocks originally formed the southern boundary of the brecciated fault zone into which the dolerite was subsequently intruded. The two blocks on the northern boundary appear to have been broken off from the ends of the third block, leaving a projection in the centre and have moved northwards. They have moved together slightly, perhaps only a few inches, since the distance between them is 3 inches less than the total length of the projecting part of the third block. This larger block is assumed to be *in situ*, since the dolerite tapers out to the west and terminates with a micro-breccia.

The main vertical joints of the granite cut through the dolerite and aplites, indicating the jointing is younger than the dyke phase.

Petrography

(*a*) *Granite and aplogranites*

Megascopically the granite is a mottled pink and dark green coloured rock ; its texture is porphyritic, with orthoclase crystals of 2–2·5 cm. in length, set in a medium-grained groundmass.

In thin section the principal minerals present are quartz, perthite, plagioclase, biotite, and hornblende. The granite is relatively poor in accessory minerals. Quartz occurs both in anhedral and subhedral forms. Weak undulose extinction and numerous fractures are characteristic of the quartz crystals which frequently exhibit a micro-pegmatitic intergrowth with perthite and plagioclase. Less common is the true granophyric intergrowth. Inclusions are common, and include plagioclase and accessory minerals. Perthite occurs in two forms, one in which the albite lamellae are clearly distinguished and the other in which the albite traces are irregular. Very much altered plagioclase cores occur in some perthites, whilst in others numerous quartz blebs occur as well. Microcline is rarely present. Plagioclase (oligoclase) occurs in subhedral form ; it is often partially altered to sericite.

A deep brown biotite occurs throughout in aggregates of several flakes, and is generally chloritized. Hornblende is normally associated with the biotite, and is also frequently altered to chlorite and epidote. The accessory minerals include abundant apatite, magnetite, ilmenite, fluorspar, sphene, and zircon.

The aplogranites are mottled pink and white rocks, fine-grained with local patches of dark minerals. They resemble the Fort Regent Granophyre. They are composed essentially of quartz, perthite, plagioclase, and patches of biotite, which is generally altered to chlorite. The accessories are iron ores, apatite, and zircon. Potash felspar and quartz are frequently intergrown, producing a characteristic micro-pegmatitic texture. The plagioclase present is slightly more acid than in the granite and is less altered, as a general rule, to sericite.

At its contact with the granite the newer rock is finer grained, contains less plagioclase, and does not exhibit the micro-pegmatitic texture of its central part. The contact, as in the field, is quite distinct. Near to the aplites the felspars and biotite of the granite appear to be less altered than usual to sericite and chlorite. Apatite and magnetite are abundant in one slide within a narrow zone of 0·5–0·75 cm. from the contact, the former occurring in large and well-formed crystals.

(*b*) *Marginal Dolerite and Dolerite Veins*

Thin dolerite veins, occurring on both northern and southern boundaries of the main dolerite, reveal many interesting features in thin section. In both there is evidence that the dolerite intrusion is post-brecciation. Fig. 1 (Plate III) shows the micro breccia from the seaward extremity of the southern dolerite tongue. The breccia which separates granite from dolerite varies in thickness between 1 and 2 mm ; where the dolerite tongues out it increases to 3–4 cm. Microbreccias are not preserved along the contacts of the main dolerite, or along the granite blocks within the dolerites where the potash felspars frequently show abrupt and shattered ends.

The breccia zone contains angular granitic materials, principally quartz, perthite, magnetite, and altered ferro-magnesians. There appears to be no mixing of dolerite material in this zone, although numerous small augites often occur in abundance along the contact. Granitic material is caught up by the dolerite, and specimens have been examined which illustrate the mechanical reaction between breccia and dolerite. Firstly, the dolerite is seen embaying the breccia, this is followed by disruption, and finally the fragments, which have been broken off, are carried along in the dolerite.

The texture of the marginal dolerite is porphyritic and contains fragments of granitic material originating from the breccia zone.

There is a strong tendency for minerals to form patches, particularly the derived material, whilst the fine-grained groundmass shows distinct banding and orientation of plagioclase laths parallel to the margin. Most of the larger augites are fractured and broken. In some cases the marginal dolerites are glassy when in contact with disintegrating breccia material.

(c) *The Dolerite*

Macroscopically the dolerites are grey-green in colour and are extremely fine-grained considering the width of the dyke. Small felspar crystals 2–3 mm. in length can, however, be distinguished.

At its centre the texture of the dolerite varies considerably over relatively small areas. Microscopically examined the felspar laths are found to vary enormously in thickness and in length. The augite present occurs as small euhedral and subhedral crystals, penninite and magnetite are common. Scattered throughout are patches of altered granitic material—quartz, potash felspar, and biotite. Whilst the texture varies locally from sub-ophitic to intergranular, the texture of the whole is best described as glomeroporphyritic.

The quartz present occurs in small irregular and embayed fragments, which show undulose extinction and contain minute inclusions, including one flake of brown biotite showing hexagonal crystal form. Fragments of potash felspar are less abundant, in fact they are almost entirely altered to quartz and sericite. Minute fragments of brown biotite occur sporadically, whilst granular epidote occurs occasionally. Plagioclase occurs in laths and is only partially altered, X′ 010 18–22° corresponding to labradorite (An 55).

Conclusion

The igneous rocks of Jersey present many problems in the determination of their age, owing to the complete absence of fossiliferous strata in the island. The granite of the Dicq Rock is one of the older granites of Jersey, probably of Pre-Cambrian age (Wells and Wooldridge, 1931, Mourant, 1933). The aplogranites most likely represent the late stage features of the granite, occupying fissures within it, due to contraction upon cooling of the main mass. Whilst it is impossible to state the age of the fault breccia and the dolerite, it is suggested that they are of Armorican age. Recent work upon the granites of south-west Jersey (Henson, 1947) indicates an Armorican age to the granites and dolerites of this area, the latter being mainly in the same general W.S.W.–E.N.E direction as the dyke described above. Dolerites having an approximate N.–S. direction are later, being of the same age as the mica lamprophyres.

To the Research Board of the University of Nottingham acknowledgment is made of a grant, making possible the research now being carried out on the plutonic and associated rocks of Jersey (F. A. H.). Mr. R. Robinson and Major J. C. M. Manley have assisted in the field by digging and in detailed measurement of the dolerite. Their kind co-operation and assistance is acknowledged.

EXPLANATION OF PLATE

FIG. 1.—Ordinary light. × 30. Section shows the micro-breccia (0·75–1·0 mm. in width), 5 cm. from the end of a dolerite tongue. The margin of the granite shows fractured quartz and altered perthite ; fragments of these minerals form the bulk of the micro-breccia, with some chloritized ferro-magnesian minerals. Within the marginal dolerite are derived fragments of granite.

FIG. 2.—Ordinary light. × 30. Contact between granite and dolerite in the main dyke. The biotite present has been considerably altered, due to the intrusion dolerite, with the formation of octahedra and rhombic dodecahedra of magnetite. Also present are altered felspar, quartz, hornblende, apatite, zircon, and epidote.

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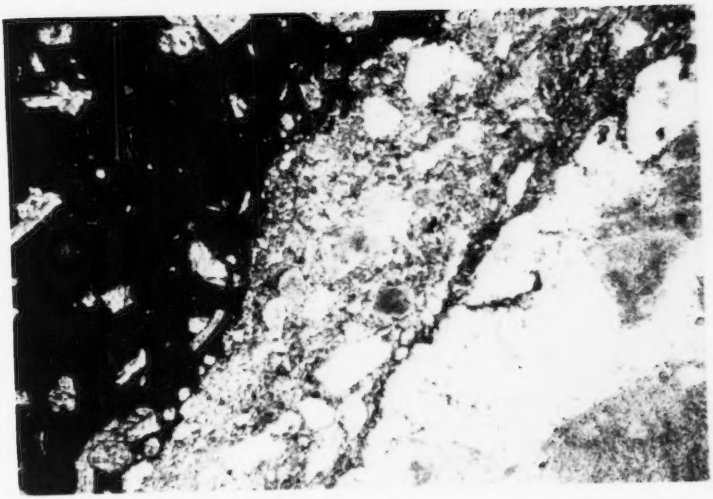
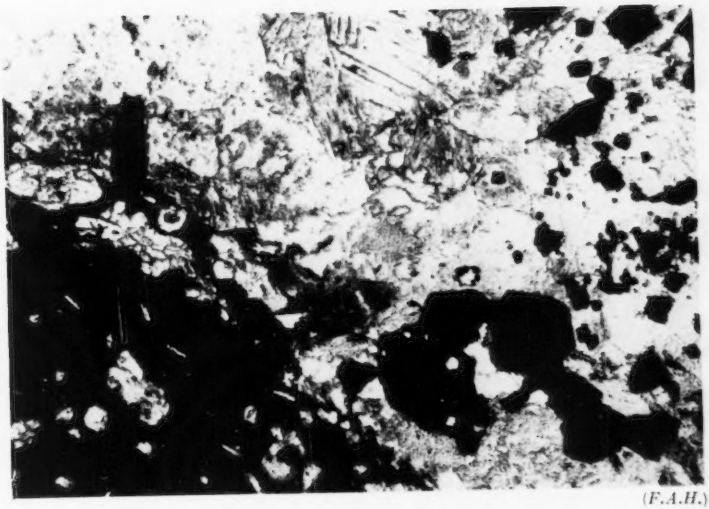


FIG. 1



(*F.A.H.*)

FIG. 2

DYKE PHENOMENA OF THE DICQ ROCK.

Evolution of *Delocrinus* to *Paradelocrinus*, and Description of *Stuartwellercrinus argentinei* sp. nov.

By HARRELL L. STRIMPLE

(PLATE IV)

ABSTRACT

The transition of *Delocrinus* to *Paradelocrinus* is demonstrated by a group of specimens collected by Mr. Allen Graffham from the Iola limestone of Kansas. Description of *Paradelocrinus iolaensis* sp. nov. is given, and the geological range of the Permian genus *Stuartwellercrinus* is taken into the Pennsylvanian (Upper Carboniferous) with the presentation of *Stuartwellercrinus argentinei* sp. nov. from the Wyandotte limestone of Kansas.

Delocrinus Miller and Gurley

Delocrinus subhemisphericus Moore and Plummer

Pl. IV, figs. 8–15

A SMALL group of Delocrinids collected by Mr. Allen Graffham from the Iola limestone formation of Kansas is of unusual interest because of the tendency toward elimination of the single anal element (anal X) from the dorsal cup. Of 34 calices studied, 33 are readily assigned to *Delocrinus subhemisphericus* Moore and Plummer (1940, p. 258). There are minor variations, which is to be expected in any group of fossils, but in this instance there is a striking demonstration of progressive evolution without loss of specific identity. It is possible to readily follow the transition from *Delocrinus* to *Paradelocrinus*. Probably the ratio of normal specimens to advanced forms is somewhat distorted because all of the specimens collected at this horizon by Mr. Graffham are not available, and it is assumed the greater number of advanced forms have been retained.

The paratype figured by Moore and Plummer (1940, pl. 20, fig. 3) from the Lane shale at Kansas City is taken as a typical example—anal X rests solidly on the truncated upper extremity of post. B, well within the dorsal cup, which is termed " Normal Type ". In the selection observed, 17 specimens were found to conform to such a requirement. In 12 specimens there is no contact between anal X and post. B ; the lower extremity of the anal plate and the upper extremity of post. B both terminate in a point, yet the anal X is still an integral part of the dorsal cup and has an outer surface confluent with adjoining RR. This is termed " Advanced Type " and illustrated by Pl. IV, figs. 8–10. Four specimens are considered " Extreme Type " as illustrated by Pl. IV, figs. 11–15, in which anal X is retained only as a rudimentary element, located in a notch between the articular facets of r. post. and l. post. RR, near their innermost margins.

It is fortunate that one specimen in the selection is a distinct representative of *Paradelocrinus*, thus permitting a complete study of the evolutionary development. Description of the form is given later in this paper.

Quite probably some species assigned to *Paradelocrinus* have originated in the erisocrinids, through development of a basal concavity and a spherical outline.

Variations in *Delocrinus subhemisphericus.*

	Normal Type.	*Advanced Type.*	*Extreme Type.*
Iola limestone formation . . .	17	12	4
Lane shale formation (after Moore and Plummer)	not given	2	0

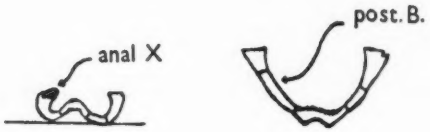
Stratigraphical distribution of Delocrinus subhemisphericus.—Moore and Plummer (1940, p. 261) give the type locality of *Delocrinus subhemisphericus* as Lane shale, upper part of the Kansas City Group, Missouri Series, Pennsylvanian, at Kansas City, Missouri. They do not report the species in collections studied from Texas. The specimens used here are from near the top of the Raytown limestone member, Iola limestone formation, Kansas City Group, at the cement plant quarry near Iola, Kansas. Moore considers the Dewey limestone formation of north-eastern Oklahoma as the probable equivalent of the Iola limestone of Kansas; however, there have been no specimens of *D. subhemisphericus* observed in the collections made by the author from the Dewey limestone.

Paradelocrinus Moore and Plummer

Paradelocrinus iolaensis sp. nov.

Pl. IV, figs. 5–7, Text-fig. 1*a*

Dorsal cup mildly pentagonal in outline when viewed from above or below. Base deeply concave; IBB five small elements, sharply downflared, and there is no angulation at meeting with BB; BB five, large elements curving evenly out of the funnel-like basal concavity;



(*a*) (*b*)

TEXT-FIG. 1 (*a*).—Cross-section of *Paradelocrinus iolaensis* sp. nov., holotype. × 1⅓ approx.

TEXT-FIG. 1 (*b*).—Cross-section of *Stuartwellercrinus argentinei* sp. nov., holotype. × 1⅓ approx.

BB circlet petal shaped when viewed from below, median portion of each plate depressed so that the suture actually occupies a ridge-like raised area. The lowermost extremities of RR are prominent, articular facets slope slightly outward and are rather narrow ; outer ligament furrow is thin but well defined and the ligament pit is sharply impressed ; muscle areas are very shallow, and lateral ridges rather high. At the meeting of r. post. R and l. post. R it is seen that a narrow protuberance or extension of the r. post. R curves into the articular area. A long narrow anal plate is present in the interarticular notch behind the extension.

Columnar scar is circular in outline and very small. Arms have not been observed.

Measurements.—

	Holotype. mm.
Height of dorsal cup	4·9
Width of dorsal cup	15·0
Ratio of height to width	0·32
Width of IBB circlet	2·5
Length of BB	4·5
Width of BB	6·3
Length of RR	4·3
Width of RR	9·0
Length of suture between radials	3·3
Length of suture between basals	4·0

Horizon and Locality.—Near the top of the Raytown limestone member, Iola limestone formation, Kansas City Group, Missouri Series, Pennsylvanian, at cement plant quarry, N.E. 1/4 Sec. 2, T. 25 S., R. 18 E., near Iola, Kansas (American Pennsylvanian = European Upper Carboniferous).

Holotype.—Collected by Mr. Allen Graffham, of the University of Nebraska. To be deposited in the U.S. National Museum.

Remarks.—This species is closer to *P. dubius* Moore and Plummer than any other described species. The depression of median portion of the basal plate, protrusion of lowermost extremity of each radial and funnel-like basal cavity are all typical of the lower Pennsylvanian species and has not previously been observed by the author in middle or upper horizons. *P. iolaensis* has a shallower cup than *P. dubius.*

Stuartwellercrinus Moore and Plummer

Stuartwellercrinus argentinei sp. nov.

Pl. IV, figs. 1–4, Text-fig. 1*b*

Dorsal cup turbinate-shaped, pentagonal outline when viewed from above and IBB are readily visible in side view. Five IBB expand evenly from the cone-like depression formed by the columnar impression ; 5 BB, large, hexagonal in outline, mildly tumid ; 5 RR, large,

smooth, pentagonal in outline. Articular facets are nearly horizontal except for a slightly raised area on the left of what is assumed to be the r. post. R. There is no discernible notch or anal plate, and the projection probably served the function of such an element.

Columnar scar is mildly pentagonal in outline. Stem and arms have not been observed.

Measurements.—

	Holotype. mm.
Height of dorsal cup	7·9
Width of dorsal cup	14·0
Ratio of height to width	0·56
Height of OBB circlet	1·6
Width of IBB circlet	5·1
Length of BB	4·6
Width of BB	5·9
Length of RR	4·1
Width of RR	8·6
Diameter columnar scar	2·4
Length of suture between radials	3·0
Length of suture between basals	2·4

Horizon and Locality.—Argentine limestone member, Wyandotte limestone formation, Kansas City Group, Missouri Series, Pennsylvanian (Upper Carboniferous), near 33rd and Roanoke Streets, Kansas City, Missouri.

Holotype.—Collected by Mr. Allen Graffham. To be deposited in the U.S. National Museum.

Remarks.—The species is assigned to *Stuartwellercrinus* with reservation. As defined by Moore and Plummer (1940, p. 328) the genus has only three IBB, and the arms are unknown for any described species. *Cibolocrinus trinodus* Weller has five IBB and was assigned by Moore and Plummer (1940, p. 134) to *Spaniocrinus* Wanner (1924, p. 292) with reservation. It is quite probable the entire group will eventually be placed under *Spaniocrinus*. Presence of three IBB in these inadunates only indicates fusion which is not of generic importance in itself. The pentamerous symmetry of *S. argentinei* when viewed from above is typical of *Erisocrinus*, however, the base of that genus is flattened or mildly concave, so that IBB are not visible in side view. The mild tumidity of BB plates and shallow concavity of lower portions of RR serve to readily separate *S. argentinei* from closely related species.

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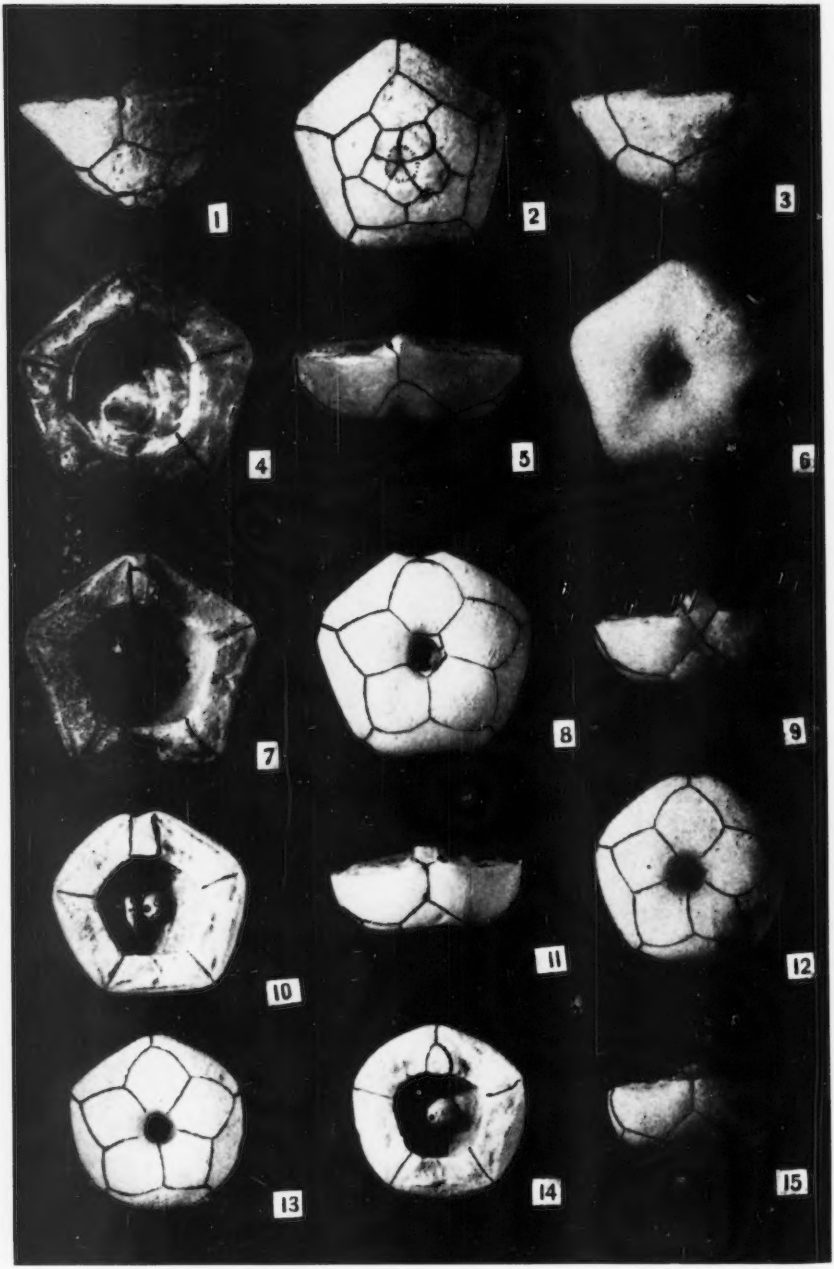

H. L. Strimple Photo.

DELOCRINUS, PARADELOCRINUS AND *STUARTWELLERCRINUS ARGENTINEI* sp. nov.

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EXPLANATION OF PLATE

(All figures approx. twice natural size.)

FIGS. 1–4.—*Stuartwellercrinus argentinei* sp. nov., posterior, basal, anterior and summit views of holotype from Wyandotte limestone formation, Kansas City, Missouri.

FIGS. 5–7.—*Paradelocrinus iolaensis* sp. nov., posterior, basal, and summit views of holotype from Iola limestone formation, Iola, Kansas.

FIGS. 8–10.—*Delocrinus subhemisphericus* Moore and Plummer, basal, posterior, and summit views of a specimen demonstrating "Advanced Type", Iola limestone formation, Iola, Kansas.

FIGS. 11–15.—*Delocrinus subhemisphericus* Moore and Plummer, specimens demonstrating "Extreme Type". Figs. 11–12.—Posterior and basal views of large cup. Figs. 13–15.—Basal, summit, and posterior views of most advanced cup observed. Iola limestone formation, Iola, Kansas.

CORRECTION

Correction to Strimple, *Geol. Mag.*, 1948, LXXXV, 113–116, Pl. X, for *Peremistocrinus*, read *Perimestocrinus*.

CORRESPONDENCE

THE ORIGIN OF RED SANDSTONES AND CONGLOMERATES

SIR,—Mr. J. B. Scrivenor's paper on the New Red Sandstone of South Devonshire, in the *Geological Magazine* for December, 1948, was of particular interest to me because, while I have examined the rocks in question only casually, I have had many opportunities to study red beds in other regions, particularly in western United States. To this may be added years of observation of the deposits now being made in arid and semi-arid regions, both temperate and sub-tropical.

From the descriptions and photographs in Mr. Scrivenor's article, I should infer with confidence that most of his conglomeratic beds were deposited as alluvial fans. Those which are distinctly but complexly stratified suggest the work of intermittent streams—muddy, but seldom loaded to full capacity. The unstratified or obscurely stratified deposits, containing angular debris and even boulders mixed together, strongly suggest mudflows, or in some cases deposits made by transient floods fully loaded with debris. Both kinds of deposits are typical of semi-arid regions such as parts of Utah and Nevada. Alluvial fans made by floods descending short steep ravines in desert regions may leave deposits consisting almost entirely of poorly sorted angular debris. Longer streams, having an opportunity to carry fragments farther, and hence to abrade them notably, have sub-angular or even well-rounded pebbles. The typical mudflow is entirely unsorted, unstratified, and may contain boulders of large size.

The colour of these red deposits varies with the proportion of clay, sand, and gravel. As the red iron oxide exists in a very fine state of division, the deposits containing little but clay are generally of a dark red or even chocolate colour, while those with but little clay may be only pink or tawny.

While there is good evidence that some red beds have been deposited in lakes, such an environment is generally unfavourable, unless the lakes are shallow and intermittent. In permanent lakes of any considerable depth, the bottom waters are ordinarily in a reducing condition, owing to the presence of decaying organic matter. Such deposits are normally some shade of grey or black, even where the inflowing streams bring in brown or red mud. This does not rule out the probability of deposition of red mud in small temporary shallow lakes incidental to the building of a river flood plain.

A dilemma is posed by the fact that red soils, which are probably the source of most red continental deposits, are characteristic of well-drained hilly regions, subject to a hot climate with generous rainfall, and the further fact that red beds commonly bear evidence of having been deposited under semi-arid or even arid conditions. Both requirements may be satisfied in regions where streams rising in a moist tropical region flow out into an arid plain, as along the north-west side of the Deccan Plateau, in India. Any other combination of conditions that would permit red soils to be produced by chemical weathering and yet would protect them from chemical reduction after transport and deposition would also meet the requirements of the case.

Mr. Scrivenor is troubled by the dimensions that seem to be required for the supposed alluvial fans in the case of the New Red Sandstone. It may be pointed out that in western United States and other regions alluvial fans of more than ten miles radius are rather common, and much larger ones are known. The very large fans generally have gradients of less than one degree, whereas small torrential fans of less than one mile radius may range from four to six degrees or, in the case of mudflow fans, as high as fifteen degrees.

ELIOT BLACKWELDER.

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AN OCCURRENCE OF AUTHIGENIC FELSPAR AND QUARTZ IN YOREDALE LIMESTONES

SIR,—The insoluble residues from the Simonstone, and Middle Limestones of Darnbrook Fell, and from the same limestones on the ridge between Littondale and Wharfedale contain authigenic quartz and felspar crystals.

The authigenic quartz calls for little comment. The crystals range in size from ·03 × ·01 to ·27 × ·05 mm., and are prismatic in habit with pyramidal terminations. They contain abundant inclusions which are highly birefringent.

The felspars range in size from ·05 × ·025 mm. to ·175 × ·06 mm. The crystals are triclinic and elongated along the *a* axis. The faces commonly present are (001), (010), (101), (1$\bar{1}$0), but the last of these may not be developed. Usually the crystals come to rest on (001) and show clean sharp outlines. When turned on to (010), however, the (101) faces are seen to be irregular and the junctions between these and the (001) faces are not sharp. In extreme cases these junctions are so rounded that the crystal is barrel-shaped. Since the other faces are clean and have sharp junctions, these irregular features are hardly likely to be due to fracture or erosion, and it is assumed that they are original characteristics.

Average measurements for some of the interfacial angles are :—

(110) : (1$\bar{1}$0) 56° (32 measurements)
(001) : (101) 43° (10 measurements)

Other angles (not averages) are :—

(001) : (110) 72°
(101) : (110) 64°

On (001), the extinction angles measured from the edge of the pinacoid range from 1°–6°. All (001) sections show twinning and the two sets may both extinguish in + direction. These sections are length fast (elongation along the a axis) and give refractive indices of 1·529 and 1·537 (± ·001). The variation in thickness due to the presence of the (101) faces produces a gradation in the interference colour from light grey at the apices to yellow or orange at the centre.

(010) sections show no twinning and give extinction angles of about 15° measured from the edge of the pinacoid. The extinction angles may be positive or negative. Extinction is sometimes undulose. The refractive indices on this section are 1·529 and 1·531 (± ·001). The section is length fast (elongation along the a axis).

Approximate values for the refractive index are therefore $\alpha = 1{\cdot}529$; $\gamma = 1{\cdot}537$; birefringence = ·008. These values and the optical characters in general, approximate to Albite.

Twinning of an unusual character is seen on all (001) faces. It consists of twins on the Carlsbad law combined with wedge-shaped Albite lamellae, together with rotation twinning about the a axis. Considerable variety is to be found—ranging from almost simple Carlsbad to almost pure Albite in character, but the second rotational element is always present. Occasionally, re-entrant angles may be seen on the crystal faces.

Inclusions are invariably present and consist of granular black material, partly concentrated near the centre of the crystal and partly disseminated throughout it.

So far as the writer is aware, the only previously recorded examples of authigenic felspars in Britain are those described by D. L. Reynolds,[1] and there are no previous records of the occurrence in Britain of authigenic quartz and felspar together.

W. W. BLACK.

THE UNIVERSITY
NOTTINGHAM.
30th January, 1949.

[1] Reynolds, D. L., 1929. Some new occurrences of authigenic Potash Felspar. *Geol. Mag.*, lx, p. 390.

THE TERM " MAGMA-TYPE "

SIR,—Like Professor A. Holmes (*Geol. Mag.*, 1949, p. 71) I am grateful to Mr. M. K. and Dr. A. K. Wells (*Geol. Mag.*, 1948, p. 349) for the opportunity offered to me of expressing my opinion about names applicable to the two prevalent basalt types of the British Tertiary province. In my work bearing on this province, I have not only ceased to employ the term " magma-type " but have also abandoned the attempt to include in one type rocks belonging to the plutonic and volcanic associations. For the latter I have used the name " lava-type " (*Bull. Volcan.*, 1940, Sci. ii, vol. vi, p. 113). In this particular work, I have employed Kennedy's terms—olivine-basalt and tholeiitic basalt, but I have since come to the conclusion that these terms are not only unsatisfactory, but can be highly misleading. Although the difference between these two lava types is very striking, the difference is not expressed by the names olivine-basalt and tholeiitic basalt, for olivine is sometimes present in basalts of the so-called tholeiitic type, and several tholeiite types, such as Largs, Salen, and Corrie types belong to the, so-called, olivine-basalt type. Instead of the above-mentioned names in dealing with the two prevalent lava-types of the British Tertiary province, I prefer to use the following terms :—

1. Hebridean Type (being the prevalent lava type in the Hebrides) to replace Plateau Magma-Type (*Mull Memoir*) and Olivine-Basalt Magma-Type (Kennedy).

2. Causeway Type (as occurring in the Giant's Causeway district) to replace Non-Porphyritic Magma-Type (*Mull Memoir*). Tholeiitic Magma-Type (Kennedy).

These two lava-types are extremely contrasted rock types, but the difference between them is not expressed by the prefixes olivine- or tholeiitic, but by the general chemical and mineralogical set up. For example, the Hebridean Type is characterized by plagioclase (labradorite) being more abundant than pyroxene, while the Causeway Type is characterized by plagioclase (andesine) being less abundant than pyroxene.

These two types exhibit minor variations mainly in respect of alkalies and silica, and can be subdivided into the following sub-types : Crinanite and Plagiophyric sub-types of Hebridean Type (Plagiophyric is to replace Porphyritic Central Magma-Type of *Mull Memoir*) and Trachydolerite (Mugearite) and Staffa sub-types of Causeway Type.

This scheme does away completely with the attempt to apply mineral or textural terms to the lava-types of the British Tertiary province, and thus localizes these types and prevents their being confused with rock-types belonging to other localities or periods. To take examples, the Tertiary olivine-basalts are by no means identical with the Carboniferous olivine-basalts, and the Tertiary tholeiite basalt differs in detail from the Carboniferous quartz-dolerites. Regional names may help to clear up this confusion and restrict the lava-types to their respective localities. The more we think of age and area in regional petrology the better and clearer are our descriptions and comparisons. This is why I would like to protest not only against the use of names for so-called magma types, but also against the use of names for rock-types based on characters related to these of rock-types from other areas.

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NEWCASTLE UPON TYNE.
28*th March*, 1949.

REVIEWS

PROCEDURE IN TAXONOMY. By E. T. SCHENCK and J. H. MCMASTERS; 2nd edition, revised by Myra Keen and S. W. Muller. pp. vii + 93. Stanford University Press (Oxford University Press), 1948. Price $2.50.

Students of palaeozoology will welcome the reappearance of Schenck and McMasters' *Procedure in Taxonomy*, with its introductory chapters and its reprint of the English version (Biological Society, Washington) of the International Rules of Zoological Nomenclature. The second edition is enlarged, rearranged, and in part rewritten, and the summaries of Opinions Rendered are brought up to No. 194, February, 1947.

THE IMPORTANCE OF UPWELLING WATER TO VERTEBRATE PALEONTOLOGY AND OIL GEOLOGY. By M. BRONGERSMA-SANDERS. Verh. K. Nederlandsche Akad. Wetenschappen, afd. Natuurkunde; Tweede Sect., xlv, No. 4, 1948.

The gist of the argument developed in this thesis is that the upwelling of water rendered lethal by concentration of dinoflagellates is a cause of mass mortality among fishes, etc. It is documented in respect of recent occurrences and plausible in the suggestion that such things have happened in the past. Certain peculiarities in the sediment from the azoic zone of Walvis Bay recall features of bituminous fish shales, and the author hints at a novel explanation of the common association of petroleum with salt.

O. M. B. B.

KLOCKMANN'S LEHRBUCH DER MINERALOGIE, 13th edition, revised by P. RAMDOHR. Stuttgart (F. Enke Verlag), 1948, xii + 674, 606 text-figures, 47.80 DM. (unbound), 50 DM. (bound).

This new edition of Klockmann's well known textbook of mineralogy, as revised by Professor P. Ramdohr, is a very welcome addition to the standard texts on mineralogy at present available. The work is divided into two roughly equal portions, Part I dealing with general mineralogy and including sections on crystallography, optical and other physical properties, crystal structure and crystal chemistry, occurrence and paragenesis, economic uses of minerals, and a valuable section on famous mineral localities. Part II gives a systematic description of most known minerals (including lattice constants and structure type where these have been determined), and there are excellent detailed indices.

Two minor criticisms may be offered. The symbol XX for crystals is perhaps allowable in the descriptive portion of the text but should not be used throughout Part I, and far too many different symbols are used for refractive indices instead of adopting one standard set.

S. R. N.

MINERALS AND MINERAL DEPOSITS. By W. R. JONES and DAVID WILLIAMS (No. 202 of The Home University Library of Modern Knowledge). Oxford University Press, 1948, vii + 248, 56 text-figures. 5*s*.

This little book aims at interesting the layman in various aspects of the subject of minerals and in this it should succeed, as the subject-matter is clearly and attractively presented. After considering the composition of the earth's crust, the shapes of minerals and their internal structure and physical characters, the common rock types, and economic mineral deposits, the authors deal with the distribution of the chief metalliferous minerals, the search for mineral deposits (which includes an account of geophysical methods of prospecting), the extraction of minerals and metals, minerals in the industrial age, and some international aspects of mineral resources. There is a glossary of minerals and rocks mentioned in the text. The chapter on internal

structure of minerals calls for particular comment as here may be found some account of types of bonding and the importance of ionic size and charge in the formation of minerals, topics still neglected all too often in books on minerals.

Although primarily intended for the general reader, the book will be of value to all students of geology who wish to know something about mineral deposits and their importance in the modern world.

S. R. N.

SEQUENCE IN LAYERED ROCKS. By R. R. SHROCK. pp. xiii + 507, with 397 text-figs. New York, Toronto, London: McGraw-Hill, 1948. Price 45*s*.

There are immense areas where, overwhelmingly, dips and faults are normal. Within them an observer, such as William Smith, can assume with little risk of error that he knows the relative age of two neighbour formations as soon as he has established the direction of inclination of their contact. There are other extensive areas where dips, though often exceeding 90°, seldom reach 180° (true). In them, dips, which follow the direction of fold-pitch, can still as a rule be used to settle age problems without further qualification; but the more numerous limb-dips can only be employed if associated cleavage or drag-folding allows us to discriminate between normal and reversed fold-limbs. Last of all there are particularly disturbed areas, where dips quite commonly surpass 180° (true). Here the stratigrapher must abandon dip altogether as a criterion of age, and look elsewhere for assistance. He may find it in fossil succession, or in some clearly marked major unconformity; or alternatively in one or other of a great variety of intimate indications of original up-or-down, which have proved of increasing importance in comparatively recent research. Perusal of Shrock's extremely interesting and helpfully illustrated book leaves the impression that the most widespread criteria are supplied by: current and graded bedding in detrital deposits; stromatalites (probably algal) in limestones; and pipe amygdales and accommodation deformation of pillows in lavas.

Shrock's review of British and American literature is fuller than any previously attempted. He lists 737 publications grouping them according to author and subject; but unfortunately omits page references to his own text, such as one is accustomed to find in an author-index.

Let us begin by noting a few historical items. J. Kelly, in Ireland, was using current bedding to distinguish normal and reversed dips as early as 1864 (p. 251)—though modern practice only seems to have started with (? W. M.) Davis sometime before 1910 (p. 251). J. B. Jukes and A. Geikie noted the top and bottom difference of symmetrical ripple marks in 1872 (p. 113). I myself am credited, somewhat to my surprise, with the first recorded recognition of the up-or-down value of graded bedding in 1906 (p. 82); but, as is well known, I did not appreciate the possible wide application of this criterion until educated in 1927 by Canadian and American geologists—and these dated their training back to C. K. Leith, of Wisconsin University, let us say from 1913 (p. 82). J. Barrell employed algal structures in 1913 (p. 287). B. N. Peach was perhaps the first to use pipe amygdales as an up-or-down criterion (p. 353—Peach published in 1911; J. Nicol was much earlier in a successful employment of pipes to demonstrate inversion—but Shrock, quoting, p. 352, from a quotation, has not realized that Nicol's pipes were "worm"-tubes, not amygdales). M. E. Wilson since 1911 has been elucidating lava successions, an extremely important matter in the Canadian Precambrian, by pillow forms (p. 364). The use of dip and unconformity in simple country is, of course, as old as geology. The availability of pitch as a guide to age relations in regions of intermediate complexity depends largely upon R. Pumpelly's rule that "the degree and direction of the pitch of a fold are often indicated by those of the axes of the minor

plications on its sides", published in 1894 (p. 432). "Van Hise, Leith, Mead, and others of the Wisconsin group" seem to have been mainly responsible for fruitful combination of stratal dip with cleavage and drag-fold phenomena, "although the principles they applied and refined . . . had been developed many years before by Heim (1878), Loretz (1882), and others" (p. 446). Shrock's comments, combined with, for instance, those of G. Wilson in the *Proc. Geol. Assoc.*, 1947, give us a fair idea of the growth of knowledge in this matter; but it would be very welcome some day to have an ordered critical account from the main protagonist, C. K. Leith.

Stratified partial infillings of cavities, such as shell interiors in sediments and vesicles in lavas, have as yet only provided minor assistance in unravelling folds; but they are very attractive, and Shrock has given them special attention (pp. 2, 4, 281–4, 306, 320–6, 350–1, 376–383). His main references are to A. Hadding, 1929, and J. S. Cullison, 1937, 1938, for sediments, and J. D. Dana, 1845, and W. M. Davis, 1880, for lavas. I am certain Shrock will welcome a recently recorded analogue (*Q.J.G.S.* for 1944, p. 17) to what he calls F. K. Morris' "bathtub rings" (p. 377). "Differentially eroded fossils" as criteria of up-or-down are covered by a single example (p. 319). To this one may usefully add G. W. Lamplugh's apt refutation of a famous inversion hypothesis applied by F. L. Kitchin to a particular exposure of Gault Clay (*Q.J.G.S.*, 1922, p. 9).

Shrock's book may be likened to a reservoir with an extraordinarily wide catchment area and destined to irrigate a very varied and as yet only partially developed field of research. It is particularly pleasant to find references to 18 papers by E. M. Kindle, whose observations and experiments always repay careful study; also to many writings of Kindle's colleagues on the Canadian Geological Survey, who like the Wisconsin School across the border were well ahead of us in Scotland in utilizing various up-or-down criteria. Some few of Shrock's entries should encourage healthy criticism, but most of them are obviously well founded, and many are provocative of further speculation. For instance, Wilson's discovery that the upper pillows of a pillow lava are generally moulded on the lower (p. 365) suggests that pillows have usually been added from above and have rolled down into place. If so a pillowy lava-top must usually be distributed by carry on an underlying molten stream, which, of course, by peripheral escape may be establishing new sources of pillows. Again, Shrock suggests that study of gas-plus-solid inclusions in the porphyritic quartzes of rhyolites may afford valuable indications of the relative orientation of crystal to gravity at the time of growth (p. 375). This certainly encourages a novel approach to the perennial magma-migma controversy that centres on granite. Anyone taking up the matter should first study L. Hawkes on glomero-granular texture (*Min. Mag.*, 1929, p. 168).

Shrock constantly points to need for caution in applying any particular up-or-down test. Consider a *Productus*. During life it lay convex downwards, so as to be able to open. After death, if agitated by waves it tended to wobble over into the position of most stable equilibrium. This, as Sorby pointed out in 1908, is convex upwards (p. 316).

Readers will probably realize by now that Shrock does not intend his book to be a mere guide to recognition of inversion. This idea does indeed supply a background, but it is often almost lost sight of behind a rich growth of natural history. Much interesting material, for instance, has been gathered to illustrate cyclic or rhythmic sedimentation (pp. 27–40). The earliest of a series of references is to J. A. Udden, 1912 (p. 34). Of course, the phenomenon had attracted attention long before the start of the present century. Thus, B. N. Peach, in a presidential address to the Royal Physical Society of Edinburgh in 1885, was able to say that "when the succession", representing a cycle within the Carboniferous Limestone Series of Scotland "is complete the following is the arrangement of the strata in ascending order: (1) limestone charged with ordinary marine fossils; (2) shales yielding stunted marine forms; (3) sandstone; (4) fireclay with the roots

of plants which is overlain by a coal seam. . . . The bed of limestone which frequently forms the roof of a coal seam represents another depression of the land surface, and the return of marine organisms forming the first stage in the same [next similar] cycle of physical conditions. . . . The same cycle of physical conditions must have been repeated again and again" (*Proc. Roy. Phys. Soc.*, vol. ix, p. 17; see also vice-president's address, 1914, vol. xix, p. 251). I had written this much when, on opening T. Robertson's "Rhythm in Sedimentation", in the 1948 *Trans. Edin. Geol. Soc.*, I found a very apposite reference to J. W. Dawson (*Q.J.G.S.*, 1854, p. 15), in which appears: "It is remarkable that in almost every instance" in the Coal Measures of Nova Scotia "the conditions for the formation of these limestones and their allied *Modiola*-shales have followed immediately on the formation of layers of coal based on underclays".

Of the finding of records there is no end. Let us therefore congratulate Shrock on not unduly delaying the appearance of his book in the vain endeavour to reach completeness. At the same time we can share his half expressed hope that some one whose home tongue is not English may before long produce a parallel contribution. Meanwhile, let us conclude this notice with a word or two in relation to over-condensation of terminology.

I confess I read with something of a shock a paragraph entitled "Chilled Top and Bottom Margins", which starts: "Ancient flows, as well as those of recent formation, have a chilled zone along both upper and lower margins. The upper zone is usually much thicker than the lower" (pp. 348, 401). It so happens that chilled-margin phraseology grew up a very long time ago among Scottish geologists who, *in the sense in which they use the terms*, find that lavas can be distinguished from minor intrusions by *never* showing chilled tops and *very seldom* chilled bases, except in the case of pillow lavas (this nowadays is their main reason for interpreting lava pillows as, if one cares to use the phrase, intrusions into water). The apparent contradiction of Scottish and Canada-American statement in the matter is, I think, due in part to laxity in our Scottish wording. "Chilled margin" for us has always meant "compact chilled margin". We have never spoken of a covering of glassy froth or a layer of pillows as a chilled top. We shall in future, I hope, aim at being more explicit. However, the laxity is not altogether on our side. It scarcely seems right for Shrock to speak of a chilled *margin* or *top*, for there appears to be usually a very gradual increase of grain size from the top of a flow to within "a few inches of the bottom" (cf. H. C. Cooke, W. F. James, and J. B. Mawdsley, 1931).

Finally, I may offer a warning against accepting too readily Shrock's verb "to face", in the sense in which Canadians use "to top" and I myself "to young". The difficulty of remembering that "to face" means "to present what was originally the top face" (p. 17) is illustrated by the fact that on p. 34 Shrock becomes self-contradictory in the matter. "To top" is less likely to be misunderstood than "to face", for it involves only one unexpressed idea, namely originality. On the whole I prefer "to young", because, though barbarous, it is self-sufficient.

E. B. BAILEY.

THE PALAEOGEOGRAPHY OF THE MIDLANDS. By PROFESSOR L. J. WILLS. pp. 144, 38 figures, and 5 plates. University Press of Liverpool, 1948. Price 10*s.* 6*d.*

This volume is written in the same concise and reflective style which characterizes the author's earlier and larger book on the physiographical evolution of the whole of Britain. Evidence and inference are skilfully combined in continuous narrative. Professor Wills calls wherever necessary upon evidence beyond the boundaries of the Midlands, and among the illustrations are twelve palaeogeographical maps covering the whole area of the British Isles and two covering western Europe.

The succession of post-Archaean events is grouped and discussed as an

alternating series of six continental phases and five marine phases, beginning with terrestrial denudation of the Pre-Cambrian surface and the marine Cambrian transgression. In his account of Ordovician geography the author favours the idea of a southern sea, with fauna of Grés de May type, extending into Central England to provide a local source for the Ordovician quartzite pebbles of the Midland Bunter. A map of Upper Salopian geography, taking account of the cores of Denbighshire Salopian type drawn long ago from borings near Harwich, shows shallow Midland waters flanked by a geosynclinal sea to the north-east as well as to the north-west. In a discussion of the facies and correlation of the Downtonian and Dittonian, the author concludes that both series should be retained as Silurian. Our lack of precise knowledge concerning the palaeogeography of the Dinantian transgression is stressed. The account of Namurian and Westphalian conditions includes comparative illustrations of rhythmic sedimentation in the Dudley and Cannock areas, and an interesting diagram of the pre-Halesowen unconformity.

The section devoted to the New Red Sandstone, in which all deposits from Keele Beds to Keuper are grouped, contains a great deal that is new. The relations and ages of many of these red rocks, and particularly of the host of local breccias and conglomerates, have long been a cause of argument. Professor Wills proposes a satisfying palaeogeographical synthesis, a modified nomenclature and a correlation which may not be inconsistent with Sherlock's views on the British Permo-Triassic rocks. The Enville and Clent Breccia Groups are equated with the Rotliegende. The Lower Mottled Sandstone is renamed the Bridgnorth or Dune Sandstone Group ; and it is suggested, following work by F. W. Shotton, that this group may be correlated with the Penrith Sandstone, and thus be of Zechstein age. The term Moulding Sand Group is proposed for the Upper Mottled Sandstone ; and Bromsgrove Group as an alternative for the Lower Keuper Sandstone.

After a well-illustrated chapter on late Mesozoic and Palaeogene times, the author discusses the development of pre-Pleistocene drainage systems, with particular attention to the effects of mid-Tertiary uplift of the now-visible coalfields. Finally, there are two chapters on the Older and Newer Drifts which, for the sake of brevity are written as a consecutive, historical account, without full quotation of evidence. Although the author expresses diffidence about their style, they will stand as a valuable key to the complicated literature on the Midland Pleistocene. The whole book will be a stimulus and a source of pleasure to any geologist who is interested in the evolutionary interpretation of stratigraphy.

A. J. B.

USEFUL ASPECTS OF GEOLOGY. By S. J. SHAND. 3rd edition, pp. 182, with 30 text-figures. London : Murby (Allen and Unwin). 1947. Price 10*s.* 6*d.*

We welcome the third edition of this most useful little book. The original work owed much of its inspiration to the author's experiences in South Africa, a country where even twenty-five years ago geology was taken seriously, and not regarded as the hobby of a few cranks. In that land there are few fossils to complicate the subject, and the stress is mainly on structure and mineralogy.

Here we have an enormous amount of useful information clearly expressed in a much condensed form, often in sentences almost epigrammatic in their terseness and point. The book can be strongly recommended to the growing number of people who realize the importance of geology in underground exploration, especially as regards oil-finding and water-supply, two subjects of special current importance in this country at present.

R. H. R.

GEOLOGY. By H. H. READ. pp. 248 with 30 figures. Home University Library. Oxford University Press. 1949. Price 5*s*.

This is a peculiarly difficult book to review, since so much depends on the standpoint of the reviewer—whether, to put it shortly, it is to be taken as wildly unorthodox, or as completely up to date. The author's own opinions, as set forth in several recent Presidential Addresses, are well-known, and they are all here. It remains to be seen whether they are to become orthodoxy.

The book consists of five chapters, of which the first is mainly historical, beginning with da Vinci, then Lehmann and Füchsel in Thuringia, who were almost forgotten later; Desmarest; Werner and his followers; Hutton and William Smith. Lyell may perhaps be now regarded as the first really modern geologist, although he was at first regarded as a heretic.

The second chapter contains a discussion of the origin of sediments, with special emphasis on facies—and a preliminary account of isostasy and the problem of the permanence or otherwise of continents and oceans and the question of continental drift, which are discussed more fully in the next chapter. This is followed by a section on classification and nomenclature of systems. The names accepted for the larger divisions are Palaeozoic, Mesozoic, and Tertiary, the inconsistency being excused on the ground that nobody can spell the *zoic* form for the Tertiary.

It may be noted here as specially interesting that the method of age-determination by lead-helium ratios seems to have been swallowed by Authority without any fuss, such as usually accompanies novelties of the first rank.

The next chapter is the most exciting in the book, for it is here that we come up against the author's own particular *doxy*, namely the granite problem and the classification of the igneous and metamorphic rocks. It is emphasized that no one has ever seen a granite magma consolidating, as basalt can be seen any day in a volcano. The formation of all granitic rocks, however it is done, takes place in depth. It is impossible to discuss the whole subject here. It must suffice to say that the author returns to what is practically Lyell's classification, with the important addition of the theory of migmatites—but there seems to be no mention of basic fronts. There can be little doubt that some form of granitization is now accepted by everybody for at any rate the larger masses, although some smaller masses, especially dykes and veins are probably formed by direct solidification of granite magma. It may be noted that in discussions of the role of granite magma it is never made clear where it is supposed to come from. However, granite batholiths may now be regarded as the extreme form of migmatite—the *room problem* makes any other solution impossible.

The author's final classification of rocks, then, may be summarized as: Neptunic (= Sediments); Volcanic; and Plutonic (= granitic + metamorphic), metamorphism being here considered as comprising what is commonly called regional, i.e. the metamorphism of the shields, ordinary thermal or contact and dynamic being excluded.

In his discussion of continental drift, which is dealt with largely in opposition to transoceanic land-bridges, the general impression left is that the author believes that it happened, from purely geological evidence, although no efficient cause has yet been found, but this is by no means the only instance of such a state of affairs in geology.

The fifth and longest chapter consists of a discussion of world-history, mainly from the tectonic point of view. This chapter is of extraordinary interest and remarkably good. Only one definite error has been noticed concerning the transition from Jurassic to Cretaceous in Britain "in Yorkshire marine conditions continued into Cretaceous times". In fact, in Yorkshire there is here a long gap in the succession, Portland, Purbeck, and lowest Cretaceous being absent.

Altogether, this is a fascinating little book, only 239 very small pages of text, and should do much to spread the knowledge of the latest developments of geology—though it may be a bit of a shock to some people.

R. H. R.

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